

LEAN SYSTEM AND INNOVATION

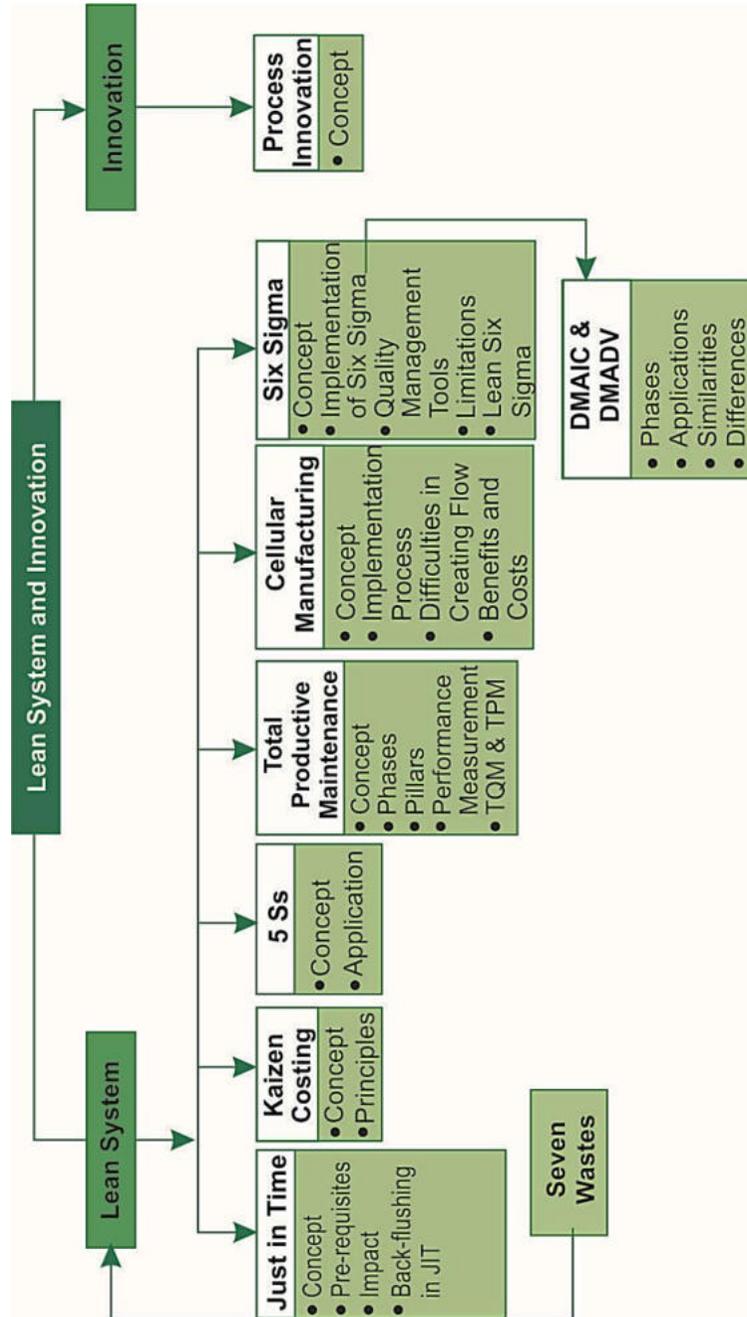


LEARNING OUTCOMES

After studying this chapter, you will be able to:

- EXPLAIN the lean system
- ADVISE on application aspects of just-in-time system, kaizen, 5S & total productive maintenance
- APPLY and evaluate six sigma as a quality improvement method
- EVALUATE the scope of process innovation.

CHAPTER OVERVIEW





A. LEAN SYSTEM

Lean System (a generic but universal incarnation of Toyota Production System) lays its foundation on the premise of lean thinking, which is an organized management philosophy for aiming to reduce process waste without sacrificing productivity within a manufacturing system to maximise the value of the product to the customer. Hence, lean implementation emphasizes the importance of optimizing workflow through strategic operational procedures while minimizing waste and being adaptable.

To start, a right mindset is required. A manager needs to be a 'lean manager', the one who leans on the value chain by identifying those value chain activities which 'providing maximum value to customers' and eliminating others (non-value-added activities or wastes). While doing so, a lean manager needs to carry the reverse engineering (backward process) ideology.



Do You Know?

What are the wastes that a lean system will reduce?

There are Seven Wastes classified by Taiichi Ohno, the father of the Toyota Production System -

- *Overproduction*: Producing ahead of demand.
- *Inventory*: Having more inventory than what is minimally required at any point in the process, including the end-product.
- *Waiting*: Waiting includes products waiting on the next production step.
- *Motion*: People or equipment moving or walking more than what is required to perform the process.
- *Transportation*: Moving products that are not actually required to perform the process.
- *Defects (non-right first time)*: That required repair or rework.
- *Over-Processing*: Unnecessary work elements (non-value-added activities).

Some of the techniques that advance lean thinking and are explained in further sections of this chapter are Just-in-Time (JIT), Kaizen Costing, 5S, Total Productive Maintenance (TPM), Cellular Manufacturing/ One-Piece Flow Production Systems, and Six Sigma. These techniques, in some way or another adherence to the core principles of lean thinking, such as–

- Do right the first time (perfect first-time quality),
- Waste minimization,
- Continuous improvement,
- Flexibility (adaptability), etc.

Since a lean system follows a **single piece flow**, it is expected to result in the elimination of waste of labour, overproduction, space, defects, inventory, and transportation. Therefore, the *characteristics* of lean manufacturing are –

- Zero waiting time
- Zero inventory

- Pull processing
- Continuous flow of production
- Continuously find ways of reducing process time.

Benefits of lean management

The lean management system is expected to realise the following benefits –

- **Improved quality and fewer defects** due to single piece flow.
- **Reduced inventory** because it believes in producing, purchasing, or storing only that much inventory which is needed for the next operation.
- **It requires less space** due to manufacturing cells and squeezing machines together so that the same can be operated by single operators with the fewest number of motions.
- **Enhances overall manufacturing flexibility** because a smaller number of activities (only those that are capable of generating value) are retained in the value stream system, resulting in the organisation having more lead time to serve the customer, which enhances adaptability or flexibility.
- **It makes identifying future kaizen simpler** because single piece flow opens up the shop floor (by eliminating defects and WIP inventory), which will help to trace productive problems and improve them.
- **Ensure a safer work environment.** Since the manufacturing cells are in use, worker has to perform repeated tasks, which will reduce or eliminate the unexpected movement, which is one of the root causes of accidents at the workplace. Therefore, by eliminating the cause of accidents, lean leads to a safe environment.
- **Improve employee morale** – Production problems are easily identified and solved. Hence, quick and correct feedback towards employee work will give him more ownership and high morale.

Issues addressed by lean management

- **Low Productivity** – Lean management increases yields, enabling the organisation to generate more satisfied customers and higher profits.
- **Prolonged Cycle Time** – Complaint resolved beyond the timeline gives birth to another complaint; hence with the help of lean management manufacturing, flexibility is enhanced and there is more lead time for the organisation to resolve the issue.
- **Costly Organisation** – As a tool of waste reduction, lean management will give a chance of cost control.
- **Rampant Wastage** – Less number of activities to generate maximum value will make the value stream free of any waste (optimal use of limited factor resources). Kaizen is also used to do continuous and future improvement (waste reduction).
- **Dissatisfied Customers and Employees** – Companies need to have a program called 'WOCAS' (what our customers are saying) and high morale employees through lean management by generating value and immediate feedback, respectively.



Figure A.1 – Lean management major stakeholders



Test Your Understanding

Based upon the above discussion, can you make a couple of points to advocate lean management?

Advocates of lean management

- Lean management can be applied to any production entity, irrespective of industry.
- Principles or goals of lean management need to be defined by the organisation; hence, high flexibility is available, which makes the application of lean practices easy.
- It requires collaborative effort among departments' teams and business group/(s) within the organisation. Hence, improvement in cooperation and participation, give the feel of empowerment for the workforce, Mind it Lean is not a 'SPOC' or one department exercise.

1. Just-in-time (JIT)

A just-in-time approach is a collection of ideas that streamline a company's production process activities to such an extent that waste of all kinds, viz., time, material, and labour, is systematically driven out of the process. JIT has a decisive, positive impact on product costs.

CIMA defines:

“Just-in-time (JIT): A system whose objective is to produce or to procure products or components as they are required by a customer or for use, rather than for stock. The just-in-time system Pull system, which responds to demand, in contrast to a push system, in which stocks act as buffers between the different elements of the system such as purchasing, production, and sales”.

“Just-in-time production: A production system which is driven by demand for finished products, whereby each component on a production line is produced only when needed for the next stage”.

“Just-in-time purchasing: A purchasing system in which material purchases are contracted so that the receipt and usage of material, to the maximum extent possible, coincide”.

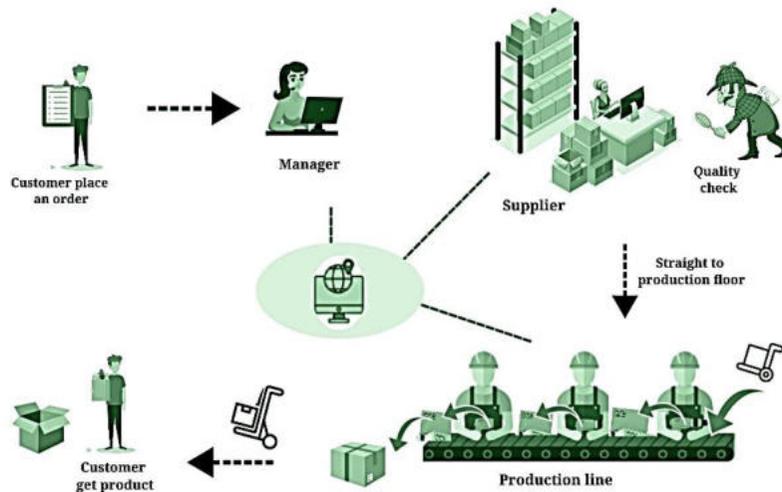


Figure A.2 – Overview of JIT System

1.1 Sequence of JIT Initiatives

JIT Purchase comprises a process that vastly reduces the amount of raw material inventory and improves the quality of received parts–

- Spare parts/ materials from suppliers on the exact date and at the exact time when they are needed.
- Straight delivery to the production floor for immediate use in manufactured products.
- Visit of engineering staff at supplier sites to examine the supplier's processes.
- Installation of an EDI system that tells suppliers exactly how much of which parts are to be sent.
- Dropping off products at the specific machines.

JIT Production comprises the process in which a company reduces the amount of work-in-process while also shrinking the number of products that can be produced before defects are identified and fixed, thereby reducing scrap costs–

- Shorten the setup times.
- Eliminating the need for long production runs and streamlining the flow of parts from machine to machine.
- Training employees on how to operate a multitude of different machines and perform limited maintenance.

JIT Support includes the processes by which a company alters supporting accounting system.

- Several alterations in the supporting accounting systems.

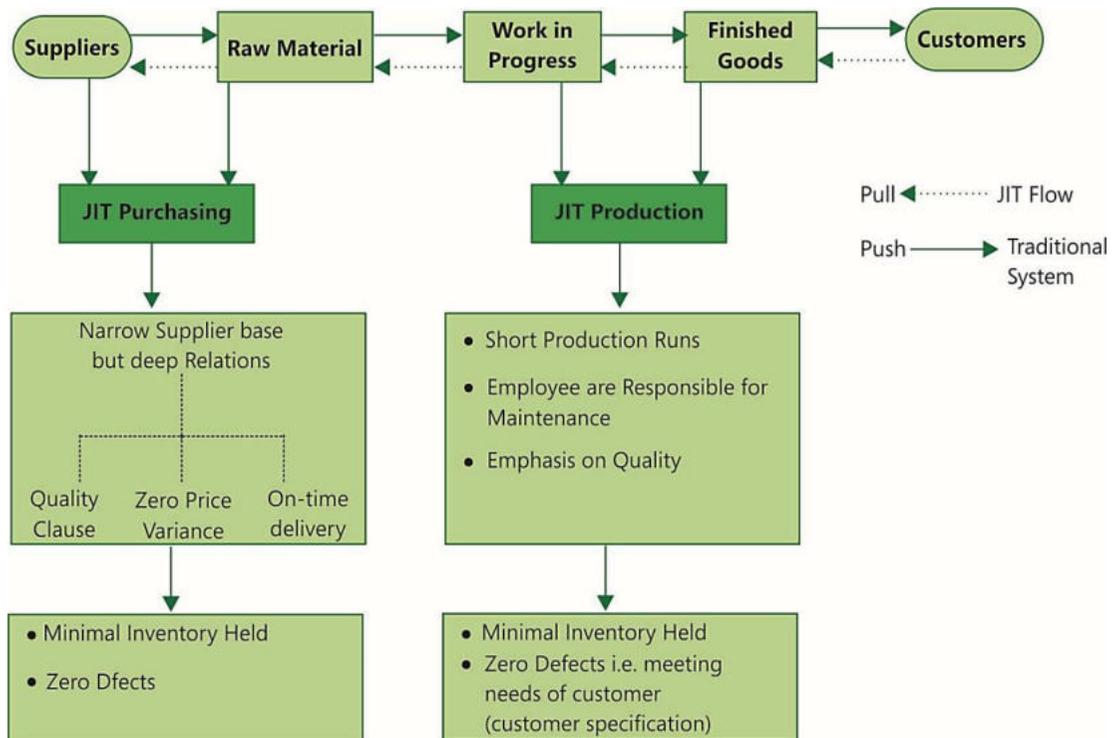


Figure A.3 – A linkage with Supply Chain

Action Plan for each of the initiatives stated above–

- To begin with, a company must ensure that *it receives products/ spare parts/ materials from its suppliers on the exact date and at the exact time when they are needed*. For this reason, the purchasing staff must investigate and evaluate every supplier and eliminate those which cannot keep up with the delivery dates.
- In addition, *deliveries should be sent straight to the production floor for immediate use in manufactured products*, so that there is no time to inspect incoming parts for defects.
- Instead, *the engineering staff must visit supplier sites and examine their processes*, not only to see if they can reliably ship high-quality parts but also to provide them with engineering assistance to bring them up to a higher standard of product.
- As soon as suppliers certify their delivery and quality, the concern must *install a system*, which may be as simplistic as a fax machine or as advanced as an *electronic data interchange system* or linked computer systems, that tells suppliers exactly how much of which parts are to be sent to the company.
- Drivers then bring small deliveries of product to the company, possibly going to the extreme of dropping them off at the specific machines that will use them first.

- Next, *we shorten the setup times for the concern's machinery*. In most factories, equipment is changed over to new configurations as rarely as possible because the conversion is both lengthy and expensive. When setups take a long time, company management authorizes long production runs, which spreads the cost of the setup over far more units, thereby reducing the setup cost on a per-unit basis. However, with this approach, too many products are frequently made at one time, resulting in product obsolescence, inventory carrying costs, and many defective products (because problems may not be discovered until a large number of items have already been completed). *'But under the JIT system, a different approach to the setup issue is followed, which focuses on making a video tape of a typical setup, instead of reducing the length of equipment setups and thereby eliminating the need for long production runs to reduce per unit costs. A team of industrial engineers and machine users examines this tape, spotting and gradually eliminating steps that contribute to a lengthy setup'*. It is not unusual, after a number of iterations, to achieve setup times of minutes or seconds when the previous setup times were well into hours.
- It is not sufficient to reduce machine setup times because there are still problems with machines not being coordinated properly so that *there is a smooth, streamlined flow of parts from machine to machine*. In most companies there is such a large difference between the operating speeds of different machines that work-in-process inventory builds up in front of the slowest ones. Not only does this create an excessive quantity of work-in-process inventory, but defective parts produced by an upstream machine may not be discovered until the next downstream machine operator works his way through a pile of work-in-process and finds them. By the time this happens, the upstream machine may have created more defective parts, all of which must now be destroyed or reworked. To resolve both of these problems, **two ways** are described below -

First – Kanban Card is a notification card that a downstream machine sends to each machine that feeds its parts, authorizing the production of just enough components to fulfil the production requirements being authorized in turn by the next machine further downstream. This is also known as a “pull” system, since kanbans are initiated at the *end* of the production process, pulling work authorizations through the production system. With this approach, there is no way for work-in-process inventory to build up in the production system since it can be created only with kanban authorization.

Second – Cellular Manufacturing (i.e., grouping machines into working cells) that will reduce excessive work-in-process inventory and defective parts. A working cell is a small cluster of machines which can be run by a single machine operator. This individual machine operator takes each output part from machine to machine within the cell, and thus there is no way for work-in-process to build up between machines. Also, this operator can immediately identify defective output, which is otherwise difficult for each machine in the cell. This configuration has the additional benefit of lower maintenance costs since the smaller machines used in a machine cell are generally much simpler than the large, automated machinery they replace. Also, because the new machines are so small, it is much easier to reconfigure the production facility when it is necessary to produce different products, avoiding the large expense of carefully repositioning and aligning equipment.

Both Kanbans and machine cells should be used together (they are not mutually exclusive) to achieve extremely low product defect rates and reduce investments in inventory (WIP).

- Before the preceding steps are completed, *it becomes apparent that a major change must also be made in the work force.* The traditional approach is to have one employee maintain one machine, which is so monotonous that workers quickly lapse into apathy and develop a complete disregard for the quality of their work. Now, with full responsibility for a number of machines as well as product quality, workers become much more interested in what they are doing. *To enhance this situation, the human resource development department of the organisation must prepare and organise training classes to teach employees how to operate a multitude of different machines, perform limited maintenance on the machines without having to call in the maintenance staff, spot product errors, understand how the entire system flows, and when to halt the production process to fix problems.* In short, the workforce must be completely retrained and focused on a wide range of activities.

A major result of having an empowered workforce is that employees are allowed to stop their machines when they see a problem and either fix it on the spot or immediately call in a repair team. In either case, the result is an immediate resolution of the bulk of performance problems. This one step has a profound impact on much of the manufacturing variance analysis. Historically, management accountants compile all kinds of variance information at the end of each month, investigate problems in detail, and then present a formal problem analysis report to management a few weeks after the end of the month. However, because the production staff resolved the underlying issues within a few minutes of their occurrence, the variance report becomes a complete waste of time. Management no longer cares what happened a month ago because it is currently dealing with current problems that will not appear on management accountant reports for weeks to come. In short, the quick response capabilities of a JIT system allow the management accountant to omit a large amount of the variance reporting that was previously an important central job function.

This approach also means that there is no need for suppliers to send invoices since the company relies solely on its internal production records to complete payments.

- *Finally, the massive changes caused by the JIT system also require several alterations in the supporting accounting systems.* Because of the large number of daily supplier shipments, the accounting staff faces the prospect of going through a large pile of accounts payable paperwork. To make the problem worse, there is no receiving paperwork because the suppliers deliver parts directly to the production operation, so there is no way to determine if deliveries have been made. *To avoid the first problem, accountants can switch to making a single consolidated monthly payment to each supplier. The second problem requires a more advanced solution. To prove that a supplier has delivered the part quantities which it claims it has, the accounting system can determine the amount of finished products created during the period and then multiply these quantities by the parts listed on the bill of materials for each product, obtaining a total quantity for each part used. The accountants then pay suppliers based on this theoretical production quantity, which is also adjusted for scrap during the production process (otherwise, suppliers unfairly will not be paid for their parts that are scrapped during the company's production process).* This approach also means that there is no need for suppliers to send invoices since the company relies solely on its internal production records to complete payments.



Concept Insight

Pros and Cons of JIT

Clearly, the changes imposed by a JIT system are profound and can greatly improve company operations when installed and operated correctly. They can also have a profound effect on product costs. So, the JIT system aims at:

- ✓ Meeting customer demand in a timely manner
- ✓ Providing high quality products and
- ✓ Providing products at the lowest possible total cost.

JIT has cons as well. The potential problems that JIT may cause include –

- ✗ It is not always easy to predict demand patterns, making it difficult to operate without inventory.
- ✗ The lack of inventories exposes an organization to any disruption in the supply chain.

1.2 Features of the JIT System

- Organise production in manufacturing cells, a grouping of all the different types of equipment used to make a given product. Materials move from one machine to another, where various operations are performed in sequence. **Material – handling costs are reduced.**
- Hire and retain workers who are multi-skilled so that they are capable of performing a variety of operations, including repairs and maintenance tasks. Thus, **labour idle time gets reduced.**
- Apply TQM to eliminate defects. As there are tight link stages in the production line and minimum inventories at each stage, defects arising in one stage can hamper the other stages. **JIT creates urgency for eliminating defects as quickly as possible.**
- Place emphasis on reducing set-up time, which makes production in smaller batches economical, and reducing inventory levels. Thus, the **company can respond to customer demand faster.**
- Carefully selected suppliers capable of delivering high quality materials in a timely manner directly to the shop floor, reducing the material receipt time.



Do You Know?

Essential pre-requisites of a JIT system

Based upon above discussion following set of pre-requisites of JIT system can be identified –

- Low variety of goods.
- Narrow supplier base, but sound and reliable trade relations with vendors.
- Efficient information system.
- Predictable demand patterns.
- Total quality management.
- Defect free materials.
- Preventive maintenance.

1.3 Impact of the JIT System on

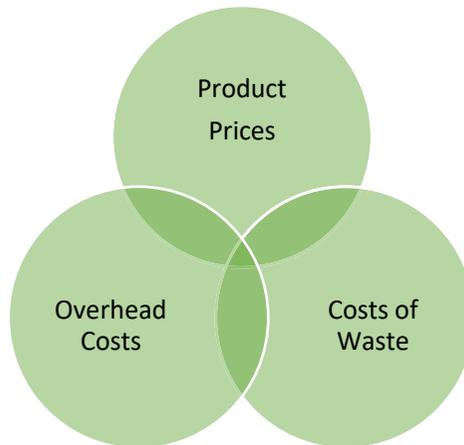


Figure A.4 – Impact of JIT System

- **Costs of Waste:** A characteristic of the JIT system is its continuous focus on eliminating all waste from a system. This can be a waste of assets or excessive inventory. It can also be a waste of time; in the case of assets, it may include unused assets for long periods of time (e.g., work-in-process inventory held in a production queue). It can also be a waste of materials, such as unnecessary levels of obsolete inventory, defective products, rework, and the like. When fully installed, a JIT system vastly reduces all these types of waste. When this happens, there is a sharp drop in several aspects of a product's cost.
- **Overhead Costs:** The costs of material handling, facilities, and quality inspection decline when a JIT system is installed. In addition, the reduction of all types of inventory results in a massive reduction in the amount of space required for the warehouse facility. Since all costs associated with the warehouse are assigned to the overhead cost pool, the amount of overhead is reduced when the costs of staff, equipment, fixed assets, facilities, and rent associated with the warehouse are sharply cut back.
- **Product Prices:** When a company achieves a higher level of product quality, along with the ability to deliver products on the dates required, customers may be willing to pay a premium. This is particularly true in industries where quality or delivery reliability is low. If customers are highly sensitive to these two factors, it may be possible to increase prices substantially. Alternatively, if these factors are not of great importance or if customers place a higher degree of importance on other factors, then there will be no opportunity for a price increase.

1.4 Back-flushing in a JIT System

Back-flushing requires no data entry of any kind until a finished product is completed. At that time, the total amount finished is entered into the computer system, which multiplies it by all the components listed in the bill of materials for each item produced. This yields a lengthy list of components that should have been used in the production process and which are subtracted from the beginning inventory balance to arrive at the amount of inventory that should now be left on hand.

Given the large transaction volumes associated with JIT, this is an ideal solution to the problem. However, there are some serious problems with back-flushing that must be corrected before it will work properly. They are –

- **Production reporting:** The total production figure entered into the system must be absolutely correct, or else the wrong component types and quantities will be subtracted from stock. This is a particular problem when there is high turnover or a low level of training for the production staff that records this information, which leads to errors.
- **Scrap reporting:** All abnormal scrap must be diligently tracked and recorded; otherwise, these materials will fall outside the back-flushing system and will not be charged to inventory. Since scrap can occur anywhere in a production process, a lack of attention by any of the production staff can result in an inaccurate inventory recording. Once again, high production turnover or a low level of employee training increases this problem.
- **Lot tracing:** Lot tracing is impossible under the back-flushing system. It is required when a manufacturer needs to keep records of which production lots were used to create a product in case all the items in a lot must be recalled. Only a picking system can adequately record this information. Some computer systems allow picking and back-flushing to coexist, so that pick transactions for lot tracing purposes can still be entered in the computer. Lot tracing may then still be possible if the right software is available; however, this feature is generally present only on high-end systems.
- **Inventory accuracy:** The inventory balance may be too high at all times because the back-flushing transaction that relieves inventory usually does so only once a day, during which time other inventory is sent to the production process; this makes it difficult to maintain an accurate set of inventory records in the warehouse.

Of all the issues noted here, the worst is a situation where the production staff is clearly incapable of providing sufficiently accurate scrap or production reporting for the back-flushing system. If there is an easily traceable cause, such as less capable workers on a particular shift, moving a few reliable employees into these positions can provide immediate relief from the problem. It may even be possible to have an experienced shift supervisor to collect this information.

However, where this is not possible for whatever reason, computer system users experience *back-flushing garbage in, garbage out (GIGO)*—entering inaccurate information rapidly eliminates any degree of accuracy in the inventory records, requiring many physical inventories counts to correct the problem. Consequently, the success of a back-flushing system is directly related to a company's willingness to invest in a well-paid, experienced well-educated production staff that undergoes little turnover.



Practical Insight

JIT Practices

A technology and innovation-led global federation of companies that provides a wide range of products wanted to implement JIT at their main plant in Nasik, as they were aware of the fact that the JIT approach would help them to operate with minimal levels of inventory. Their business objective was to encourage all suppliers' active participation in the production process. They wanted that the suppliers should be "enabled" to know of any change in the whole production process and at the same time contribute actively. This was necessary to reduce the time to respond to a situation and help the "just-in-time" approach in the production process.

Objective

- Make all the suppliers' active participation in the production process.
- Suppliers should be able to know of any changes in the whole production process and, at the same time, contribute actively.
- Update to best practices for supply strategies for 400 vendors, 150 vehicles per day, and 1,100 parts.
- Improvement in replenishment efficiency.
- A reduction in stock at the assembly line favouring flexible manufacturing.

VSS Service

Concept planning for JIT and the supply chain includes the definition of load units and their arrangement at the assembly line, the definition of the replenishment trigger concept, the design of stores and handling equipment, and a review of the method of supply from vendors.

Solution

Modular standard metal containers and totes based on Indian truck dimensions. Load units ergonomically presented to the workers.

25 JIT parts identified (supplied in sequence), a two-tier shelving system for totes with dynamic allocation and picking, and containerized supply from local vendors with round pick-up.

Reduced personnel and replenishment lead time, improved manufacturing flexibility.

Benefits

- By making the suppliers participate in the "just-in-time" method of production, they could maintain the lowest inventory level.
- Suppliers could see in real time the status of the supplies, bill settlement, and a host of other parameters.
- All active participants in a process, for instance, from a supplier to the dealer, can handle change management with the help of a particular solution and a defined process.
- Setup times are significantly reduced in the warehouse. Cutting down on set-up time to be more productive allowed the company to improve their bottom line and look more efficient.
- Having employees focused on specific areas of the system allowed them to process goods faster instead of being vulnerable to fatigue from doing too many jobs at once, which simplifies the tasks at hand.
- Increase emphasis on supplier relationships.

Illustration 1

KP Ltd. (KPL) manufactures and sells one product called “KEIA”. Managing Director is not happy with its current purchasing and production system. There has been considerable discussion at the corporate level as to use of ‘Just in Time’ system for “KEIA”. As per the opinion of managing director of KPL Ltd. –

“Just-in-time system is a pull system, which responds to demand, in contrast to a push system, in which stocks act as buffers between the different elements of the system such as purchasing, production and sales. By using Just in Time system, it is possible to reduce carrying cost as well as other overheads”.

KPL is dependent on contractual labour which has efficiency of 95%, for its production. The labour has to be paid for minimum of 4,000 hours per month to which they produce 3,800 standard hours.

For availing services of labour above 4,000 hours in a month, KPL has to pay overtime rate which is 45% premium to the normal hourly rate of ₹ 110 per hour. For avoiding this overtime payment, KPL in its current production and purchase plan utilizes full available normal working hours so that the higher inventory levels in the month of lower demand would be able to meet sales of month with higher demand level. KPL has determined that the cost of holding inventory is ₹ 70 per month for each standard hour of output that is held in inventory.

KPL has forecast the demand for its products for the first six months of year 2023 as follows:

Month	Demand (Std. Hrs.)
Jan'23	3,150
Feb'23	3,760
Mar'23	4,060
Apr'23	3,350
May'23	3,650
Jun'23	4,830

Following other information is given:

- (i) All other production costs are either fixed or are not driven by labour hours worked.*
- (ii) Production and sales occur evenly during each month and at present there is no stock at the end of Dec'22.*
- (iii) The labour are to be paid for their minimum contracted hours in each month irrespective of any purchase and production system.*

Required

As a chief accountant you are requested to COMMENT on managing director's view.

Solution**Workings****Statement Showing 'Inventory Holding Cost' under Current System**

Particulars	Jan	Feb	Mar	Apr	May	Jun
Opening Inventory* (A)	---	650	690	430	880	1,030
Add: Production*	3,800	3,800	3,800	3,800	3,800	3,800
Less: Demand*	3,150	3,760	4,060	3,350	3,650	4,830
Closing Inventory* (B)	650	690	430	880	1,030	---
Average Inventory $\left(\frac{A+B}{2}\right)$	325	670	560	655	955	515
Inventory Holding Cost @ ₹70	22,750	46,900	39,200	45,850	66,850	36,050

(*) in terms of standard labour hours

$$\begin{aligned} \text{Inventory Holding Cost for the six months} &= ₹2,57,600 \\ &(\text{₹}22,750 + \text{₹}46,900 + \text{₹}39,200 + \text{₹}45,850 + \\ &\text{₹}66,850 + \text{₹}36,050) \end{aligned}$$

Calculation of Relevant Overtime Cost under JIT System

Particulars	Jan	Feb	Mar	Apr	May	Jun
Demand*	3,150	3,760	4,060	3,350	3,650	4,830
Production*	3,150	3,760	4,060	3,350	3,650	4,830
Normal Availability*	3,800	3,800	3,800	3,800	3,800	3,800
Shortage (=Overtime*) (C)	---	---	260	---	---	1,030
Actual Overtime Hours $\left(\frac{C}{0.95}\right)$	---	---	273.68	---	---	1,084.21
Overtime Payment @ ₹159.50 [110+45%]	---	---	43,652	---	---	1,72,931

(*) in terms of standard labour hours

$$\begin{aligned} \text{Total Overtime payment} &= ₹2,16,583 \\ &(\text{₹}43,652 + \text{₹}1,72,931) \\ \text{Therefore, saving in JIT system} &= ₹2,57,600 - ₹2,16,583 \\ &= ₹41,017 \end{aligned}$$

Comments

Though KPL is saving ₹41,017 by changing its production system to Just-in-time but it has to consider other factors as well before taking any final call, which are as follows:

- (i) KPL has to ensure that it receives materials from its suppliers on the exact date and at the exact time when they are needed. Credentials and reliability of the supplier must be thoroughly checked.
- (ii) To remove any quality issues, the engineering staff must visit suppliers' sites and examine their processes, not only to see if they can reliably ship high-quality parts but also to provide them with engineering assistance to bring them up to a higher standard of product.
- (iii) KPL should also aim to improve quality at its process and design levels with the purpose of achieving "Zero Defects" in the production process.
- (iv) KPL should also keep in mind the efficiency of its work force. KPL must ensure that labour's learning curve has reached a steady rate so that they are capable of performing a variety of operations in an effective and efficient manner. The workforce must be completely retrained and focused on a wide range of activities.

2. Kaizen Costing

The kaizen (改善) is a Japanese word that means 'Continuous Improvement'.

Kaizen Costing is a cost reduction system through small, continuous, and incremental improvements. It is based on the belief that nothing is ever perfect, so improvements and reductions in cost are always possible. Kaizen goals are set based on actual results from a prior period. The goal is to reduce the actual cost of the current period in the coming period/(s).

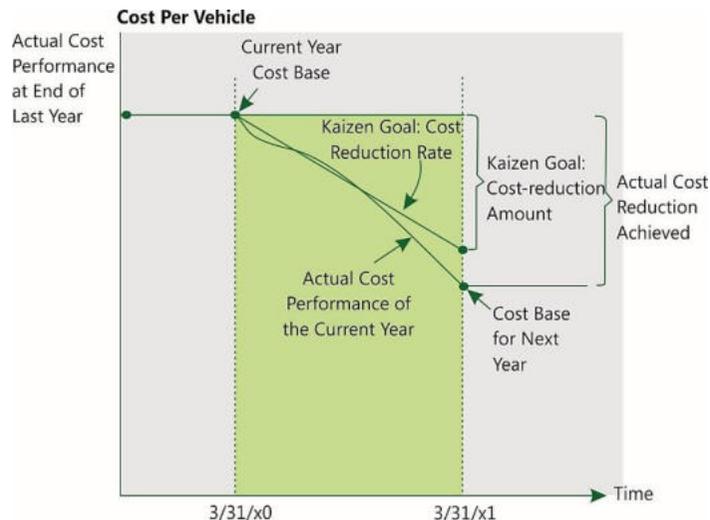


Figure A.5 – Kaizen Costing Chart used by Daihatsu Motor Company (Osaka, Japan)¹

¹ Managerial Accounting 7E By Hilton

Lean manufacturing is founded on the idea of kaizen, or continual improvement. Continuous improvement is the continual examination and improvement of existing processes and is very different from approaches such as business process re-engineering (BPR), which seeks to make radical one-off changes to improve an organization's operations and processes. This philosophy implies that small, incremental changes routinely applied and sustained over a long period of time result in significant improvements. The Kaizen strategy aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a particular process.

Some of the activities in the kaizen costing methodology include the elimination of waste in the production, assembly, and distribution processes, as well as the elimination of work steps in any of these areas. Though these points are also covered in the value engineering phase of target costing, the initial value engineering may not uncover all possible cost savings. Thus, kaizen costing is really designed to repeat many of the value engineering steps for as long as a product is produced, constantly refining the process and thereby stripping out extra costs. The cost reductions resulting from kaizen costing are much smaller than those achieved with value engineering but are still worth the effort since competitive pressures are likely to force down the price of a product over time, and any possible cost savings allow a company to still attain its targeted profit margins while continuing to reduce cost.

2.1 Kaizen Costing Process

Based on the above discussion, the process of Kaizen can be divided into three steps, namely –

Step 1 – Establishing a cost reduction goal (kaizen cost target).

Step 2 – Ascertain the gap by comparing the goal to the actual cost.

Step 3 – Formulate and implement a cost reduction plan based on value analysis.

Figure presented below can be refer in light of these 3 steps.

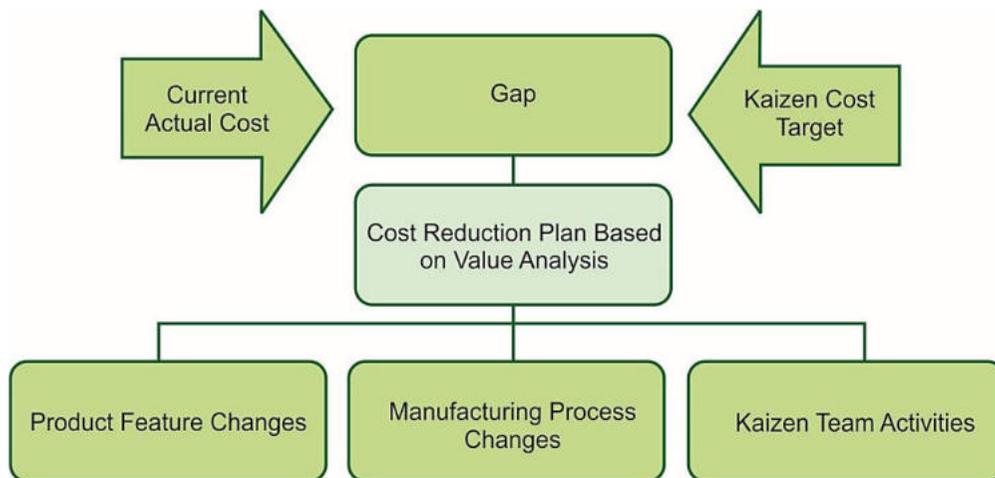


Figure A.6 – Process of Kaizen Costing

How is 'Kaizen Costing' different from 'Standard Costing'?

Standard Costing	Kaizen Costing
a. Cost control technique.	a. Cost reduction technique.
b. It assumes current work conditions.	b. It assumes continuous improvement conditions.
c. Meet cost performance standards.	c. Achieve cost reduction target.
d. For a longer period, usually year on year.	d. For a short span, i.e., Monthly or Quarterly.
e. For variance analysis, comparison is among the actual and standard costs.	e. No variance is needed to be computed. Gap is the difference between actual cost and kaizen target cost.
f. Variances need to be addressed and reported.	f. Reason for the missing target cost (Kaizen) needs to be assessed – Jidoka, etc.



Concept Insight

Kaizen Principles – The Core of Kaizen

There are 5 Fundamental Kaizen Principles that are embedded in every Kaizen tool and in every Kaizen behavior. The 5 principles are –

1. Know your customer – Understand them and their interests so that business can enhance their experience. (Aim for creating customer value)
2. Let it Flow – Everyone in the organisation aims to create value and eliminate waste. (Aim for targeting zero waste)
3. Go to Gemba – Value is created where things actually happen - go there; go to the real place. Hence, the act of visiting the shop floor in Lean and Kaizen. (Aim for following the action)
4. Empower People – Set the same goal for your teams and provide a system and tools to reach them. (Aim for organizing your teams)
5. Be Transparent – Performance and improvement should be tangible and visible. (Aim for speaking with real data)

Therefore, the premise of Kaizen practice includes –

- ✓ The system seeks gradual improvements in the existing situation at an acceptable cost.
- ✓ It encourages collective decision making and the application of knowledge.
- ✓ There are no limits to the level of improvement that can be implemented.
- ✓ Kaizen involves setting standards and then continually improving these standards to achieve long-term sustainable improvements.
- ✓ The focus is on eliminating waste, improving systems, and improving productivity.
- ✓ It involves all employees and all areas of the business.



Figure A.7 – Premises of Kaizen Practice



Do You Know?

How is the cost reduction target established (Agreed Target/ Goal)?

While establishing the cost reduction target, the workforce is empowered through the bottom-up path, i.e., asking them to participate in establishing the target and searching for or suggesting means to attain it.

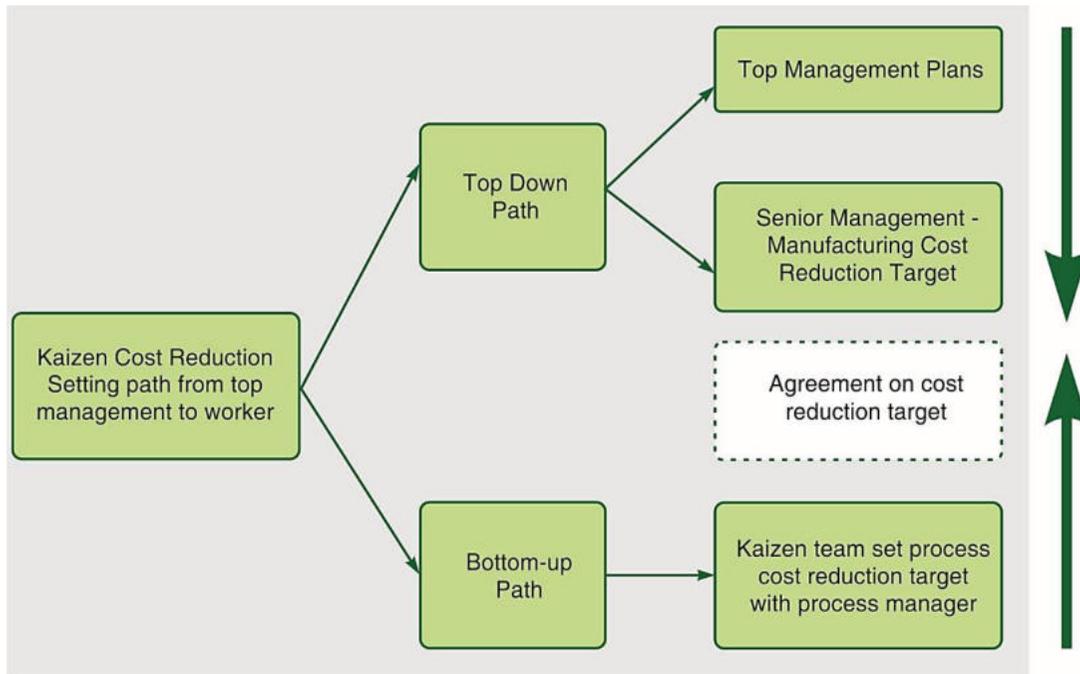


Figure A.8 – Agreement in Kaizen



Case Scenario

M. India Ltd. (MIL) is an automobile manufacturer in India and a subsidiary of Japanese automobile and motorcycle manufacturer Leon. It manufactures and sells a complete range of cars, from the entry level to the hatchback to sedans and has a present market share of 22% of the Indian passenger car market. MIL uses a system of standard costing to set its budgets. Budgets are set semi-annually by the Finance department after the approval of the Board of Directors at MIL. The Finance department prepares variance reports each month for review in the Board of Directors meeting, where actual performance is compared with the budgeted figures. Mr. Suzuki, group CEO of Leon, is of the opinion that the Kaizen costing method should be implemented as a system of planning and control in the MIL.

Required

RECOMMEND key changes vital to MIL's planning and control system to support the adoption of 'Kaizen Costing Concepts'.

Solution

Kaizen Costing emphasizes *small but continuous improvement*. Targets, once set at the beginning of the year or activities are *updated continuously* to reflect the improvement that has already been achieved and that is yet to be achieved.

The suggestive changes which are required to be adopted in Kaizen Costing concepts in MIL are as follows:

Standard Cost Control System to Cost Reduction System: Traditionally Standard Costing system assumes stability in the current manufacturing process and standards are set keeping the normal manufacturing process into account thus the whole effort is on to meet performance cost standard. On the other hand, Kaizen Costing believes in continuous improvements in manufacturing processes and hence, the goal is to achieve cost reduction target. The first change required is the standard setting methodology i.e., from earlier Cost Control System to Cost Reduction System.

Reduction in the periodicity of setting Standards and Variance Analysis: Under the existing planning and control system followed by the MIL, standards are set semi-annually and based on these standards monthly variance reports are generated for analysis. But under the Kaizen Costing system cost reduction targets are set for small periods, say for a week or a month. So, the period covered under a standard should be reduced from semi-annually to monthly and the current practice of generating variance reports may be continued or may be reduced to a week.

Participation of Executives or Workers in standard setting: Under the Kaizen Costing system participation of workers or executives who are actually involved in the manufacturing process is highly appreciated while setting standards. So, the current system of setting budgets and standards by the Finance department with the mere consent of Board of Directors required to be changed.



Practical Insight

Kaizen Practices²

Kaizen Costing becomes part of the Package. At the start of 2002 a UK company called Kappa Packaging (now part of the Smurfit Kappa Group) had a factory in Greater Manchester that made, among other products, cartons to hold bottles of drink. That year, the firm introduced a new approach to cutting the amount of wastepaper and cardboard it was producing, which stood at 14.6 percent of the raw materials consumed. The new approach included the following initiatives: a) Making employees more aware of how much waste was being produced. b) Requiring them to monitor the amount of waste for which they were individually responsible. c) Establishing a Kaizen team to find ways of reducing waste. As a result, Kappa was able to reduce waste from 14.6 percent to 13.1 percent of raw materials used by the end of 2002 and down to 11 percent in 2003. Each percentage-point saving was worth an estimated £110,000 a year.

3. 5S

5S is the foundation of the pillars of TPM (Total Productivity Maintenance). 5S is the name of a workplace organization method that uses a list of five Japanese words: **seiri**, **seiton**, **seiso**, **seiketsu**, and **shitsuke**. It explains how a workspace should be organized for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order.

² "Accurate measurement of process waste leads to reduced costs", www.envirowise.gov.uk, 2003

3.1 5S Phases



Figure A.9 – Phases of 5S

5S phases: they can be translated from the Japanese as “**sort**”, “**set in order**”, “**shine**”, “**standardize**”, and “**sustain**”.

3.1.1 Sort (Seiri)

Sort the material at the production floor or any other part of the production facility (including the extended store) into following categories –

- Not needed at all.
- Needed, but not now.
- Needed, but not here.
- Needed, but not so much quantity.

The categories suggested above are generic in nature; businesses may develop the categories as per their own choices and convenience.



Do You Know

While classifying the material into different categories, the following questions need to be answered–

- What is required?
- How much is required?
- When is/ will it be required?
- Where is/ will it be required?

Sorting can be **visual aided**; this, apart from saving time, can also help the unskilled worker or worker with limited technical understanding determine what to do with material based upon the colour of the flag attached to it. The following two categories of tags are usually used–

- Red tag – A card containing detailed information about unwanted things with a given time limit for further action to be taken.

- Yellow tag - A card containing detailed information about needed things but not now with a given time limit for further action to be taken – usually kept in store.

Sorting endorses lean thinking by helping in identifying the following –

- Obsolete items, i.e., those parts (jigs/ tools) not required as the design has become obsolete or otherwise.
- Defective items, i.e., parts that can't be used as they are, can be used, but some repair or maintenance needs to be performed.
- Scrap items, i.e., leftover material, may or may not be useful.
- Items not at their designated place (dislocated items that lay at the place where they shouldn't be).
- Unnecessary items, i.e., either extra or not useful.



Do You Know?

What benefits is sorting capable of generating?

The benefits expected from sorting include –

- Make work easier by eliminating obstacles and evaluating necessary items with regard to cost or other factors.
- Reduce the chances of being disturbed with unnecessary items.
- Prevent the accumulation of unnecessary items.

3.1.2 Set in Order (Seiton)

Set-in-order signifies the **systemic arrangement** by adherence to the 14th Principle of Management enunciated by Henri Fayol in Administrative Theory of Management, i.e., Principle of order which provides that **there shall be place for everything and everything shall be in its place**. Therefore, set-in-order arranges all necessary items into their most efficient and accessible arrangements so that they can be easily selected for use and make the workflow smooth and easy.

Purpose is to save search time and eliminate motion waste through visual management, with a search free and count free arrangement. Hence, place components according to their uses, with the frequently used components being near to the work.



Do You Know?

How to implement systematic arrangements?

- Analyse status.
- Decide which things will belong where.
- Decide how they should be put away.
- Get everybody to follow the rules through indexing, labelling, etc.

Set-in-order supports lean thinking through realising the following –

- Faster retrieval of things results in the elimination of search time.
- Opportunity to correct the abnormalities faster as visibility improves by the system itself.
- Space savings by systematic arrangement.
- Efficiency of work improves as things are.
- Available when they are actually needed.

3.1.3 Shine (Seiso)

Shine ensures there must be cleanliness ‘in and of’ everything. Obviously, if there are fewer items, then there is less to clean.

Workers are responsible for cleaning their workstations on a daily basis to ensure safety (by eliminating the scope of any accident); this will also result in a clean and pleasing workspace to work at. Cleaning includes inspection of machines, tools, or any other production (as well as supporting) facilities from all aspects, i.e., front, rear, left, right, top, and bottom.

3.1.4 Standardise (Seiketsu)

Establish and standardise the best practices at the workplace and make them part of organisation wide standard operating procedures (SOPs) so that sorting, set in order, and shine become a habit of the workforce. Organisations need to maintain SMART standards; strive for standardised orderliness so that everything is in order according to its standard. Every process must have a standard.

3.1.5 Sustain (Shitsuke)

In order to sustain the established standard, it is required to do–

- Daily Monitoring.
- Improving ownership by allocating areas.
- Using ‘Red Tag Campaign’.
- Communicating visually through fixed point photography.
- Structured communication.
- Continuous training of all employees.
- Periodic audits at all levels.
- Motivating staff through recognition.

**Concept Insight**

To standardise and sustain an organisation, it may fix responsibilities for implementing and evaluating system. Integrate these responsibilities into routine work. Check how well the system is working and sustaining itself.

3.2 Interlinking of 5S and Underlying Benefits

5S are interlinked to each other in the form of a continuous process that results in certain benefits, such as high quality, productivity and low cost with enhanced safety as shown in the figure below–

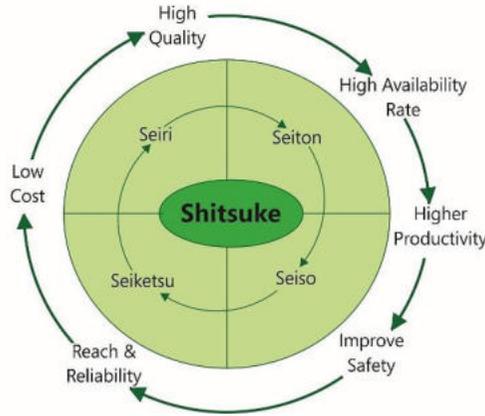


Figure A.10 – 5S and underlying benefits

3.3 5S in Lean Product and Process Development

Information is the output of engineering and design in a lean enterprise. The theory behind using 5S here is that “dirty, cluttered, or damaged surfaces attract the eye, which spends a fraction of a second trying to pull useful information from them. Old equipment hides the new equipment from the eye and forces people to ask which to use.” 5S methodology is being applied to a wide variety of industries, including Manufacturing, Health Care, Education, and Government. 5S is not only the foundation for TPM; instead, it is the foundation for various lean manufacturing techniques, as shown in the figure below –

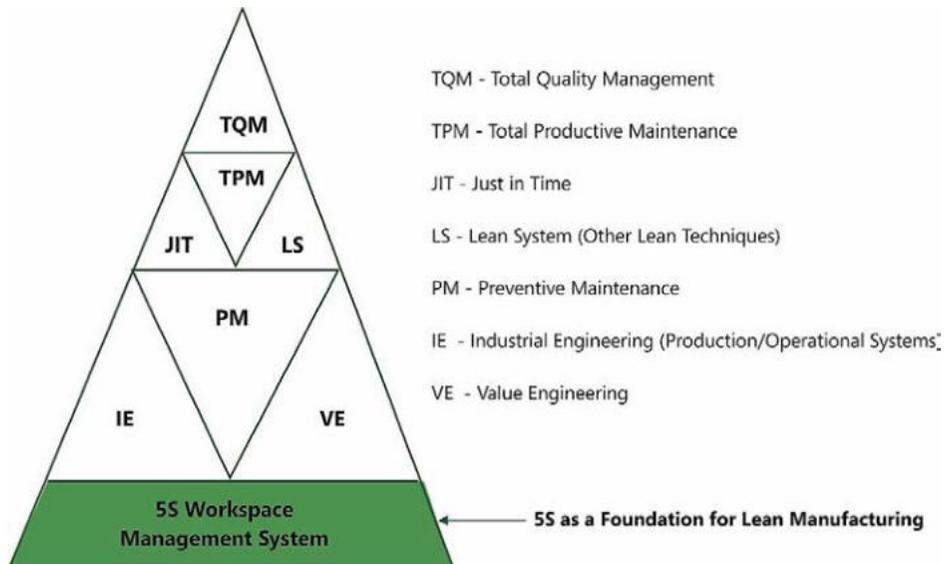


Figure A.11 – 5S as a foundation for Lean Manufacturing

3.4 5S methodology as a core enabler of continual improvement

5S helps the organisation strive towards continual improvement and innovation through the PDCA cycle. Plan and Do are enablers for continual improvement, while Check and Action are results. 5S, being the foundation of TPM (even all the lean practices that eventually led to TQM), acts as the enabler for continual improvement and fits in at the Do stage, as shown in the picture below–

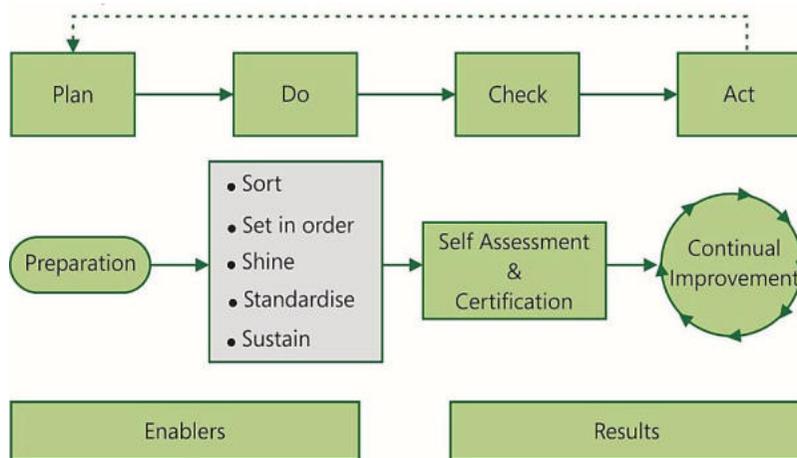


Figure A.12 – 5S implementation as part of the PDCA Cycle for continuous improvement and innovation



Case Scenario

Y & E Chartered Accountants offers a wide range of specialized, multi-disciplinary professional services that meet the immediate as well as the long-term business needs of clients. One of partner 'E' was upset with office documentation. 'E' argued that a document management solution is needed to maximize efficiency within the firm. The senior partner 'Y' has recently attended a seminar on lean system and heard the '5S'. He said that old files hide the key files from the eye and force staff to ask which to use. Accordingly, he desires to implement '5S'.

Required

ADVISE on the implementation of '5S' in Y & E.

Solution

Office processes often have huge amounts of paperwork, and this not only makes processes slower but also allows errors to be introduced. 5S is a method of both cleaning out the working area and maintaining its cleanliness to improve process quality. The 5S process is based on:

Sort (Seiri)

This is the sorting and removal of unnecessary files, papers, books, and documents in the work area. Sorting is designed to make the work area neat, organized and arranged so that relevant items can be found easily. If an item is not relevant to the work, then it should not be in the work area.

Set in Order (Seiton)

Set in order means systematic arrangement of things, i.e., arrange all necessary items into the most efficient and accessible arrangement so that they can easily be identified for use. It is advisable to have proper indexing of files and proper documentation, i.e., a proper index should be made and pasted on each file about its contents, and in that pattern of contents, documents should be kept inside the files so that specific document can easily be traced and withdrawn on time. Even inside a cupboard, paper indexing about files with their names should be pasted so that specific file can easily be traced. Same can be done w.r.t. folders in computer, right file should be saved in the right folder with an identifiable name so that anyone can easily find any file. Frequent use items should be close by, and infrequent use items can be further away in a central area. All storage areas should be clearly labelled to allow items to be put in the correct place, e.g., where did I leave the office stamp again?

Shine (Seiso)

After sorting and simplifying, it is necessary to keep the work area clean and safe. Shining is also an inspection process for the area, i.e., is everything in good condition? It is desirable to involve employees for 15-20 minutes each day to clean the work area so that they can develop the habit of cleanness. In the same way, unimportant files either in desktop or in any driver should be permanently deleted.

Standardize (Seiketsu)

A clean and tidy work area allows the process to be standardized and examined for quality or process improvements. Best practices are documented and rolled out across the work area, standards and process measures are established and displayed in the work area.

For example, a red file can be standardized for very important files (can be required anytime), a green file for important files, and a yellow file for unimportant files.

Sustain (Shitsuke)

It means to maintain discipline; this can only be achieved by auditing work areas and processes to make sure that the 5S standards are maintained. It is worthwhile to apply 5S standards continuously, i.e., daily basis, and check for any upgrades if needed, so that firm can have good management in terms of documentation, cleanness, time savings for partners as well as clients.

Overall, 5S in offices streamlines the work (low to reduce errors as well as improving process times) and employee satisfaction.

4. Total Productive Maintenance (TPM)

Total Productive Maintenance (TPM) is a system for maintaining and improving the integrity of production and quality systems. This is done through the machines, equipment, processes, and employees that add to the value of Business Organisation. This concept was first introduced by M/s Nippon Denso Co. Ltd. of Japan, a supplier of M/s Toyota Motor Company.

4.1 How can TPM be introduced in the organization?

The introduction of TPM follows four main phases:

- Preparation Stage: Establish a suitable environment and conduct programme awareness.
- Introduction Stage: Initialization of TPM, information to suppliers, customers, and other stakeholders.
- Implementation Stage: This is done with the help of eight activities referred to as pillars of TPM.
- Institutionalising stage: This is the stage of getting TPM awards.

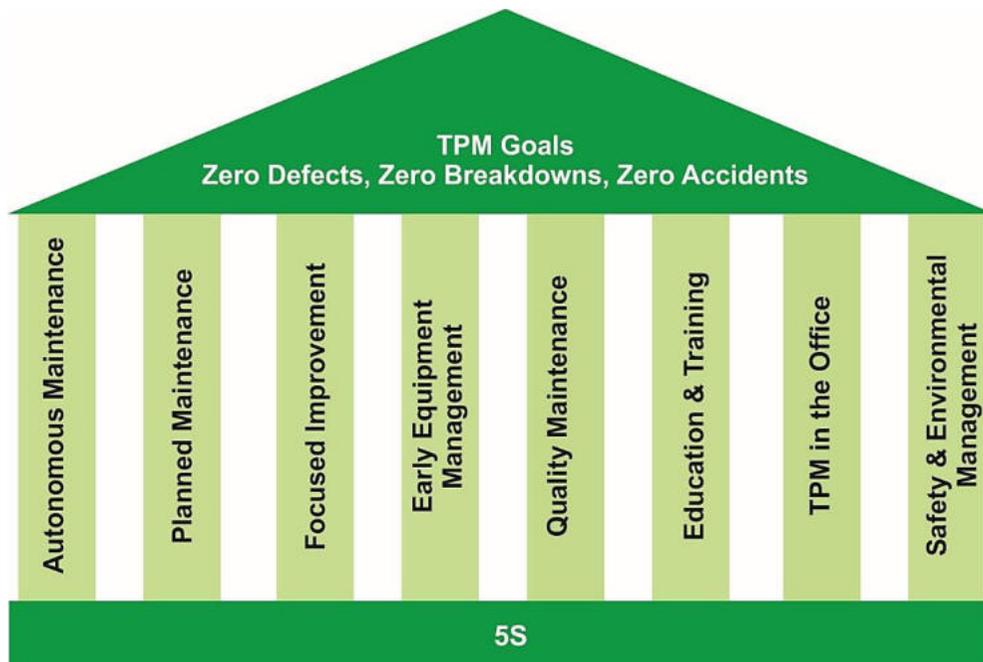


Figure A.13 – Pillars of TPM

TPM helps in keeping all equipment in top working condition so as to avoid breakdowns and delays in manufacturing processes.

TPM strategy focuses on **eight pillars** of success, with the 5S strategy as the foundation as shown in the figure. Each pillar (8 activities) relies upon certain techniques, as shown in table –

Foundation & Pillars	About	Techniques
Foundation: 5S	TPM starts with 5S. It deals with organising a workplace, which helps to recognise the uncover problems.	Seiri (sort), Seiton (set in order) Seiso, (shine), Seiketsu (standardize), Shitsuke, (sustain).
P-1: Autonomous Maintenance	Operation of equipment <i>without breakdown</i> and eliminating the defects at source through active employee participation.	Cleaning, Lubricating, Visual Inspection, Tightening of Loose Bolts, etc.
P-2: Focussed Improvement (Kaizen)	This pillar is about the <i>minor improvements made on a continuous basis</i> . This pillar aims to reduce losses in the workplace that affect efficiencies.	Kaizen Register, Kaizen Summary Sheet, Why-Why Analysis, and Summary of Losses.
P-3: Planned Maintenance	This is a <i>proper maintenance system</i> adopted for improvement in the reliability and maintainability of equipment. It aims to have zero breakdown and optimum maintenance cost.	Preventive Maintenance, Breakdown Maintenance, Corrective Maintenance, and Maintenance Prevention.
P-4: Early Management	This focuses on <i>shortening the time required</i> for product and equipment development.	Engineering and Re-engineering Processes.
P-5: Quality Maintenance	This is towards achieving <i>customer satisfaction</i> through the delivery of high-quality products.	Root Cause Analysis, and Customer Data Analysis.
P-6: Education and Training	It aims to improve knowledge/skills and enhance the morale of employees.	Training Calendar, Policies for Education and Training, On-site Training, etc.
P-7: Office TPM	Application of TPM techniques in administration to improve productivity and efficiency while eliminating losses.	Analyzing processes and procedures towards increased Office Automation.
P-8: Safety, Health, and Environment	Above all, the safety of workers is utmost importance. It aims to have zero accidents and zero health damages.	Drama, Safety Slogans, Quizzes, and Posters Making to create awareness related to safety.

4.2 Performance Measurement in TPM³

The most important approach to the measurement of TPM performance is known as the Overall Equipment Effectiveness (OEE) measure. The calculation of the OEE measure requires the identification of “six big losses”.

- Equipment Failure/ Breakdown
- Set-up/ Adjustments
- Idling and Minor Stoppages
- Reduced Speed
- Reduced Yield and
- Quality Defects and Rework

The first two losses refer to time losses and are used to calculate the *availability* of equipment. The third and fourth losses are speed losses that determine the *performance* efficiency of equipment. The last two losses are regarded as *quality* losses.



Figure A.14 – OEE

OEE may be applied to any individual assets or to a process. It is unlikely that any manufacturing process can run at 100% OEE. According to Dal *et al* (2000), Nakajima (1998) suggested that the ideal values for the OEE component measures are:

Availability	> 90%
Performance	> 95%
Quality	> 99%

Accordingly, OEE at World Class Performance would be approximately 85%. Kotze (1993) contradicted this saying that an OEE figure greater than 50% is more realistic and therefore more useful as an acceptable target.

Illustration 2

KIWI Ltd. manufactures spare parts and can be called a "high volume based" manufacturing environment. The company is using the system of TPM for maintaining and improving the integrity of the manufacturing process. There are several different automated manufacturing machines located in the plant, through which the manufacturing of spare parts is done and supplied to cater the demand in the market.

³ Factors Affecting the Implementation of a Total Productive Maintenance by Norman Herrmann.

A 12- hour shift is scheduled to produce a spare part in KIWI Ltd. as shown in the schedule below. The shift has three 15- minute breaks and a 10- minute clean up period.

Production Schedule for Automated machine NZ 10:

Cycle: 10 (seconds),

Spare parts Manufactured: 3,360,

SCRAP: 75,

Unplanned Downtime: 36 minutes

Required

CALCULATE OEE (Overall Equipment Effectiveness) and comment on it.

Solution

Calculation of Planned Production Time

	Mins.
Total time (12 hrs. × 60 mins.)	720
Less: Planned downtime	
break (3 × 15 mins.)	45
clean up time	10
Planned Production Time	665

$$\text{Availability Ratio per shift} = \left\{ \frac{665 \text{ mins.} - 36 \text{ mins.}}{665 \text{ mins.}} \right\} \times 100$$

$$= 94.59 \%$$

$$\text{Actual Production} = 3,360 \text{ parts}$$

$$\text{Standard time} = 10 \text{ seconds}$$

$$\text{Standard Time Required} = 3,360 \text{ parts} \times 10 \text{ seconds} / 60$$

$$= 560 \text{ minutes}$$

$$\text{Actual Time Taken} = 665 \text{ mins.} - 36 \text{ mins.}$$

$$= 629 \text{ minutes}$$

$$\text{Performance Ratio} = \left\{ \frac{560 \text{ mins.}}{629 \text{ mins.}} \right\} \times 100$$

$$= 89.03\%$$

$$\text{Quality Ratio} = \left\{ \frac{3,360 \text{ parts} - 75 \text{ parts}}{3,360 \text{ parts}} \right\} \times 100$$

$$= 97.77\%$$

$$\text{Thus, OEE} = 0.9459 \times 0.8903 \times 0.9777$$

$$= 82.34\%$$

Comment

Since the OEE of KIWI Ltd. is very close to 85%, i.e., world class performance level, the company should take measures to improve it and strive to attain 85% level. Availability Ratio of machine NZ 10 is 94.59%, exceeding the ideal value of > 90%, which is good; but the Performance and Quality Ratios need attention as they are below their ideal values of > 95% and > 99%, respectively.



OEE is based on three OEE factors: Availability, Performance and Quality. The calculations are as follows for each of the three main factors:

$$\text{Availability Ratio} = \left\{ \frac{\text{Operating Time}}{\text{Planned Production Time}} \right\} \times 100$$

The availability is related with the total stoppage time resulting from unscheduled downtime, process setup and changeovers, and other unplanned stoppages. It is the ratio of *operating time* to *planned production time* and takes into consideration the theoretical production time against which unplanned downtime is highlighted.

Planned down time, such as preventive maintenance, lunch break, tea breaks, etc. is not regarded as a loss in this respect.

$$\text{Performance Ratio} = \left\{ \frac{\text{Ideal Cycle Time} \times \text{Total Count}}{\text{Operating Time}} \right\} \times 100$$

'Ideal Cycle Time' is the theoretical fastest possible time to manufacture one piece.

$$\text{Quality Ratio} = \left\{ \frac{\text{Good Count}}{\text{Total Count}} \right\} \times 100$$

This is the third element of OEE. It is defined as the ratio of *total good production* to *actual total production*, sometimes called 'yield'.

Note- OEE can be calculated using the formula - (Good Count × Ideal Cycle Time) / Planned Production Time.

4.3 Connection between TQM and TPM

The connection between TQM and TPM is summarized below:

- TQM and TPM make the company more competitive by reducing costs, improving customer satisfaction, and slashing lead times.
- Involvement of the workers in all phases of TQM and TPM is necessary.
- Both processes require fundamental training and education for participants.
- TPM and TQM take a long time to notice sustained tangible benefits.
- Commitment from top management is necessary for the success of the implementation.

5. Cellular Manufacturing/ One Piece Flow Production System

A sub section of JIT and Lean System is Cellular Manufacturing. It encompasses group technology. The goals of cellular manufacturing are:

- To move as quickly as possible,
- Make a wide variety of similar products,
- Making as little waste as possible.

In the assembly line, multiple cells are used. Each cell comprises one or more machines which accomplish a certain task. The product moves from one cell to the next, each station completing part of the manufacturing process. A **U-shaped design** is given to these cells because this allows for the supervisor to move less and can more readily watch over the entire process.

Flexibility in operations is its biggest advantage. Changes are easy to make as the machines are automatic. Variety of product scaling is possible, and minor changes to the overall design are made possible by changing the overall design. Although tedious, the changes can be done precisely and quickly.

A cell is created by consolidating the processes required to create a specific output, such as a part or a set of instructions. Reduction is the extra step that is taken in the process of creating the specific output and facilitate quick identification of problems and encourage communication among employees within the cell in order to resolve issues that arise quickly. It gives massive gains on implementation in productivity and quality while simultaneously reducing the amount of inventory, space, and lead time required to create a product. It is for this reason that the one-piece-flow cell has been called "the ultimate in lean production".

5.1 Implementation Process

In order to implement cellular manufacturing, a number of steps must be performed.

First, the parts to be made must be grouped by similarity (in design or manufacturing requirements) into families.

Then a systematic analysis of each family must be performed, typically, in the form of production flow analysis (PFA) for manufacturing families or in the examination of design/ product data for design families. This analysis can be time consuming and costly, but it is important because a cell needs to be created for each family of parts.

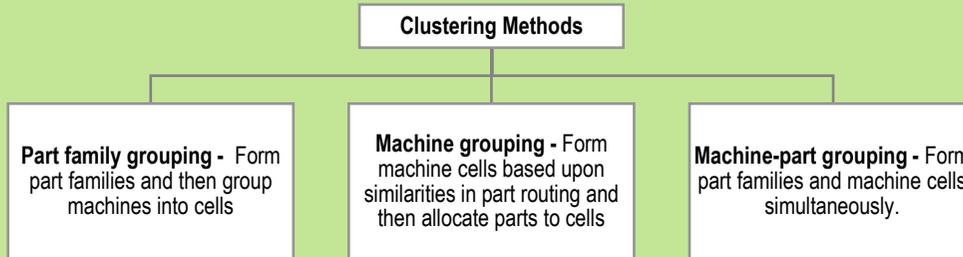
There are also a number of **mathematical models** and **algorithms** to aid in planning a cellular manufacturing centre which take into account a variety of important variables, such as "multiple plant locations, multi-market allocations with production planning, and various part mix."

Once these variables are determined with a given level of uncertainty, optimizations can be performed to minimize factors such as "total cost of holding, inter-cell material handling, external transportation, fixed cost for producing each part in each plant, machine and labour salaries."



Concept Insight

1. **Production Flow Analysis** rests on the basic idea to identify items that are made with the same processes / the same set of equipment. These parts are assembled into a part family, and the same equipment can be grouped (clustering) into a cell to minimize material handling requirements.



Note - The machine-part grouping is most significant.

2. Various **heuristic and exact methods** have been developed for grouping/clustering, but the simplest one is **binary ordering**, also known as **rank order clustering** or **King's algorithm**.
3. **Rank Order Clustering Algorithm** is a simple algorithm used to form machine-part groups.

Rank Order Clustering Algorithm

The steps in using the Rank Order Clustering Algorithm are as follows:

1. Assign **Binary Weight** ($BW_j = 2^{n-j}$) to each column j of the matrix, where n is the number/ types of components (parts).
2. Calculate the **Decimal Equivalent** (DE_i) of the binary values of each row i using the formula:

$$DE_i = \sum_{j=1}^n (BW_j)(a_{ij})$$

3. **Rank** the rows in decreasing order of their DE_i values, i.e., the largest value is ranked as 1. Break ties (if any) arbitrarily.
4. **Re-arrange** the rows in the running order of the rankings.
5. If no further rearrangement is necessary, stop. Otherwise, go to the next step, i.e., 6.
6. Assign **Binary Weight** ($BW_i = 2^{m-i}$) to each rearranged row i of the matrix, where m is the number of machines.
7. Calculate the **Decimal Equivalent** (DE_j) of the binary values of each column j using the formula:

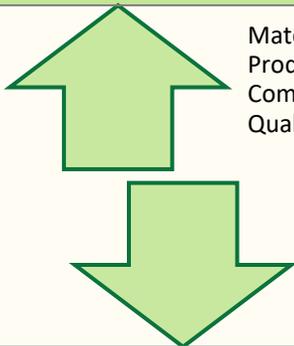
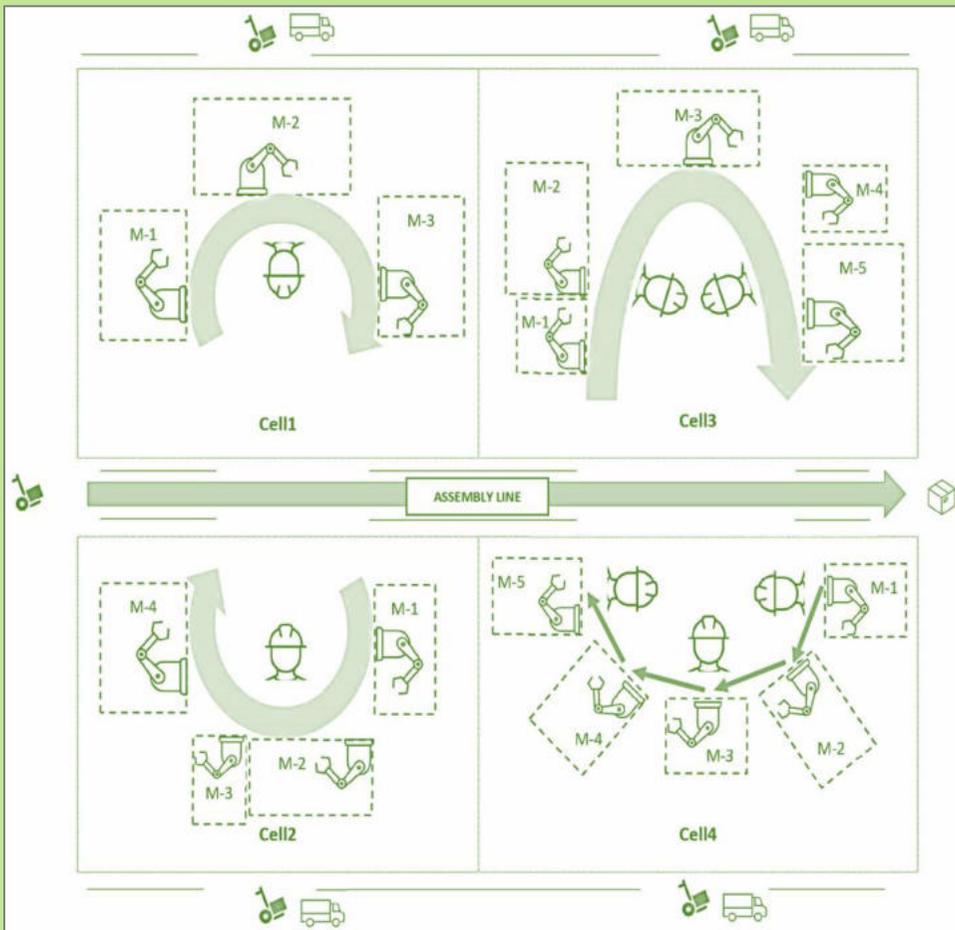
$$DE_j = \sum_{i=1}^m (BW_i)(a_{ij})$$

8. **Rank** the columns in decreasing order of their DE_j values, i.e., the largest value is ranked as 1. Break ties (if any) arbitrarily.
9. **Re-arrange** the columns in the running order of the rankings.
10. If no rearrangement is necessary, stop. Otherwise, go to step 1.



Concept Insight

Flow Shop or Assembly Line Workflow



Material flow; Machine utilization; Space utilization; Productivity (compared to process layout); Components standardization; Employee morale; Quality, etc.

Planning effort; Paper work; Setup time; Down-time; Work movement; Work-in-process; Material handling cost; Direct/indirect labour cost, etc.

Figure A.15 – Assembly line workflow

5.2 Difficulties in Creating Flow

Following difficulties need to be considered and addressed to create efficient flow in cellular manufacturing:

- Exceptional Elements
- Machine Distances
- Bottleneck Machines and Parts
- Machine Location and Relocation
- Part Routing
- Cell Load Variation
- Inter and Intracellular Material Transferring
- Cell Reconfiguring
- Dynamic Part Demands and
- Operation and Completion Times

5.3 Benefits and Costs

Scattered processes are merged to form short, focused paths in concentrated places. So constructed, by logic a cell reduces flow time, flow distance, floor space, inventory, handling, scheduling transactions, and scrap and rework (the latter because of the quick discovery of nonconformities). Moreover, cells lead to simplified, higher validity costing, since the costs of producing items are contained within the cell rather than scattered in distance and the passage of reporting time.

Production and quality controls are facilitated. Cells that are underperforming in either volume or quality can be easily isolated and targeted for improvement. The segmentation of the production process allows problems to be easily located, and it is more clear which parts are affected by the problem.

There are also a number of benefits for employees working in cellular manufacturing. The small cell structure improves group cohesiveness and scales the manufacturing process down to a more manageable level for the workers.

Workers can more easily see problems or possible improvements within their own cells and tend to be more self-motivated to propose changes. Additionally, these improvements that are instigated by the workers themselves cause less and less need for management, so over time, overhead costs can be reduced.

There are a number of possible limitations to implementing cellular manufacturing. Some argue that cellular manufacturing can lead to a decrease in production flexibility. Cells are typically designed to maintain a specific flow volume of parts being produced. Should the demand or necessary quantity decrease, the cells may have to be realigned to match the new requirements, which is a costly operation and not typically required in other manufacturing setups.

6. Six Sigma

Engineer Bill Smith introduced Six Sigma while working at Motorola in 1986. Six Sigma became well known after Jack Welch made it a focus of his business strategy at General Electric in 1995, and today it is widely used in many sectors of industry. It is a quality improvement technique whose objective is to identify and eliminate *defects* in any aspect that affects customer satisfaction. For this, six sigma uses the Quality management methods, Statistical methods, and Special infrastructure of people.

The premise of Six Sigma is that by measuring defects in a process, a company can develop ways to eliminate them and practically achieve “zero defects”. Six Sigma can be used with a balanced scorecard by providing a more rigorous measurement system based on statistics.

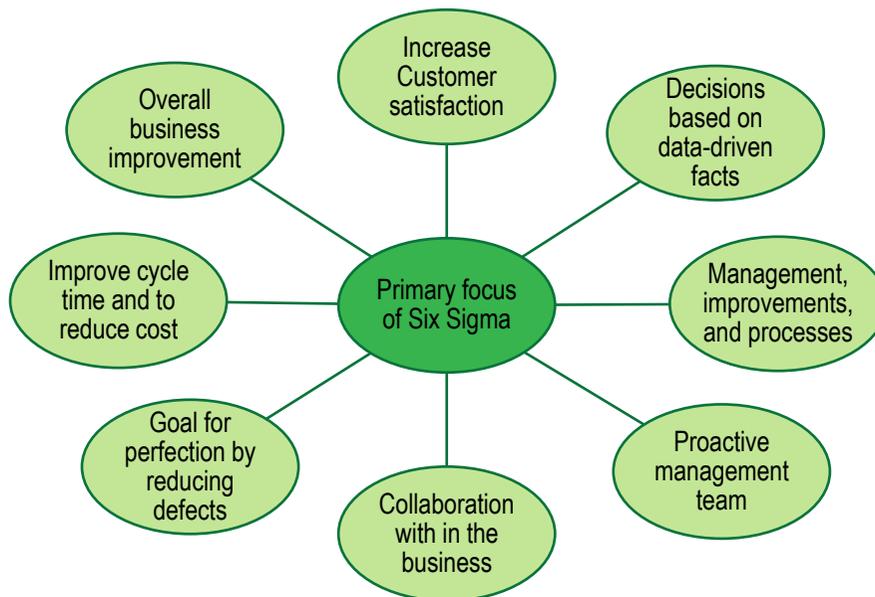


Figure A.16 – Primary focus of Six Sigma

Six Sigma practices are based upon the following assertions –

- Continuous efforts to attain a stable and predictable process, which result in no variance.
- Character of a process that can be measured, analysed, improved, and controlled.
- Achieving sustained quality improvement through overall commitment from the entire organisation, especially top-level management.

6.1 Numerical Concept of Six Sigma

'Sigma' is a statistical term that measures how far a process deviates from perfection. The higher the sigma number, the closer the process is to perfection.

The values of the Defect Percentage

Six Sigma is 3.4 defects per million opportunities or getting things right 99.99966% of the time. It is possible to develop ways of reducing defects by measuring the level of defects in a process and discovering the causes.

The Value of the Defect Percentage Under Various Sigma Levels

Sigma Level	Defects per Million Opportunities (DPMO)	Percentage Defective (%)	Percentage Yield (%)	Quality/ Profitability
1 σ	6,91,462	69	31	Loss
2 σ	3,08,538	31	69	Non-Competitive
3 σ	66,807	6.7	93.3	Average Industries
4 σ	6,210	0.62	99.38	Above Average
5 σ	233	0.023	99.977	Below Maximum Productivity
6 σ	3.4	0.00034	99.99966	Near Perfection

The second last column (in the above table) indicates the percentage of values that lie within the *control limits*. The more popular measure, the number of defects per million opportunities, is indicated in the second column.

It may not be possible to achieve 'perfect Six Sigma', but relevant benefits can be achieved from a rise from one Sigma level to another.

6.2 Implementation of Six Sigma

There are two methodologies for the implementation of Six Sigma-

6.2.1 DMAIC: This method is very robust. It is used to improve *existing* business processes. To produce dramatic improvements in business processes, many entities have used it successfully. It has *five phases*:



Figure A.17 – DMAIC

DMAIC is used under the following circumstances:

- A product or process exists.
- The project is part of an ongoing continuous improvement process.
- Only a single process needs to be altered.
- Competitor's actions are stable.
- Customer's behaviour is unchanging.
- Technology is stable.



Concept Insight

Application of DMAIC⁴

In the banking sector, DMAIC may be used as follows:

- ❑ *Define:* Customer satisfaction and loyalty have a significant impact on the financial performance of a bank. Six Sigma involves defining objectives and opportunities to improve (based on customers' feedback or complaints) in discussion with staff.
- ❑ *Measure:* In this phase, Six Sigma experts deploy quantitative procedures to collect statistical data. Then the statistical data is used for measuring the impact of the various processes on customer satisfaction. Different processes may have different impact on customer satisfaction. The measurement of the impact of individual processes helps the banks to concentrate on improving the processes that have the maximum impact on customer satisfaction. In the banking industry, wait times are said to have the maximum impact on customer satisfaction.
- ❑ *Analyse:* In this phase, Six Sigma experts analyse the data collected in accordance with the parameters set for improvement. So that the processes that directly affect customers' satisfaction can be improved at a minimum cost.
- ❑ *Improve:* In this phase, experts take corrective measures to improve processes in consultation with staff based on facts and statistics. Advanced statistical tools can also be used to study the impact of the proposed improvement initiative on business processes.
- ❑ *Control:* Control systems should be put in place to monitor the impact of the improvement initiatives through periodical review performance. If a business process is still not performing well in accordance with the desired Six Sigma levels, the process is referred back to the 'define' phase. However, if a small problem is impacting performance, then corrective measures are taken and the whole process is not referred back.

⁴ <http://www.sixsigmaonline.org>



Case Scenario

Derby Grey is a leading manufacturer of leather luggage bags (up to 62”) for style-conscious people around the globe. It is made up of two independent divisions in New Delhi. The division ‘Mx’ performs all manufacturing and packaging operations. All sales are made through the division ‘Rx’, which has 11 retail stores in New Delhi, as well as through Derby Grey’s own well-developed website. Derby Grey also has retail operations in Dubai, Kuala Lumpur, Bangkok, as well as in Singapore. These overseas businesses operate as independent subsidiaries within Division ‘Rx’.

Derby Grey revolutionized the industry by offering cheap but stylish luggage bags. Derby Grey is able to keep its prices low by offering a very basic level of service. Luggage bags are sold in boxes for customers to assemble themselves, and all deliveries are made through third party distributor ‘Costa Cruise’.

Dr. Philips (Managing Partner) is bothered about increasing sales returns and massive complaints about products purchased from Derby Grey on social media. With this concern, Dr. Philips has appointed you as a performance management expert to help the firm to execute the six sigma technique to reduce the number of sales returns and to evaluate the firm’s existing performance.

Dr. Philips has heard that Six Sigma analysis involves large quantities of data. Dr. Philips stated– “I’m not confident in our current IT systems. I doubt whether the system would be able to identify the required data related to cutting, preparation, closing, lasting, etc. These manufacturing subdivisions may be the root cause of the problem. Further, the quarterly compiled sales return data lacks enough detail. We may need to do more analysis on customer satisfaction and manufacturing quality.”

You have been given access to feedback given by customers for returning goods to measure existing performance in this area (refer below):

Difficult to assemble or pieces missing (47%) – Bags were not as demanded (24%) – Poor Quality (19%) – Arrived damaged (9%) – Arrived late (1%)

Required

ADVISE Managing Partner on Six Sigma implementation to reduce the number of sales returns using the DMAIC method.

Solution

DMAIC is a methodology of Six Sigma used to improve existing business processes. It is advisable for the Managing Partner to execute the following phases of DMAIC–

Define the process

This phase emphasises exactly *what the customer’s requirements are?* In this case, focus is precisely on *why bags are returned*. The objective of the process needs to be clear, as in this case, to *reduce the number of customer returns*. Customers expect certain minimum requirements from the manufacturing and packaging process, for example, that the bags are properly packed in boxes. They also expect the goods to be delivered undamaged within a reasonable time and at the time & date committed. Further, customers’ perceptions of quality should coincide with the price paid, though different customers may have different expectations.

Measure the existing process

This phase measures the process to determine existing performance. In this case, the sales returns figures do not show a complete picture as to why customers return bags, which of the classes belongs to 'poor packing', which belongs to 'defective item', which belongs to 'activities of other subdivisions', etc. The *ambiguity of the data and the classification of definitions will need to be addressed* to enable the process to be measured effectively.

Analyse

This phase *detects the root cause* of the problems. Possible root cause of sales returns are as follows:

- Difficult to assemble or pieces missing (47%) – Returns could be because the bags were not manufactured or packed properly in the 'Mx' division, but they could also be due to poor design, customers losing pieces, or simply being unable to assemble the bag.
- Bags were not as demanded and of poor quality (43%) – Returns could be due to defective manufacture or if the customer had merely changed their minds and no longer required the bag. In 'bags were not as demanded', the identification of 'defective items' are too vast.
- Arrived damaged (9%) – It may be that customers wrongly classified defective bags as damaged. Though bags may become damaged by the 'Çosta Cruise', only a small number of returns relate directly to them.
- Arrived late (1%) – Reasons of arrived late could be either 'Costa Cruise' could not make delivery on time or 'Mx' division could not complete the order on time, and this causes only 1% of returns, which is relatively insignificant.

Further, information could be analysed, like country wise sales returns, product wise sales, or with *more clear definition of 'defective items' from the customer's perspective*. By doing so, the firm may easily get information related to areas of the business where sales returns are high and hence be able to focus on.

Improve

In this phase, recommendations are made to *minimize or eliminate the root cause* of the problem, and then those recommendations are implemented to improve the process in a systematic manner. Derby Grey is required to *consider aspects of production or packaging which could be improved*, for example, the timely repair and maintenance of equipment or training of existing staff, etc. Further, *availability of resources and likely costs of making the improvements* need to be carefully considered.

Control

Here, control means *maintaining improved performance and future performance*. Derby Grey would be required to monitor the performance on an ongoing basis. If sales returns reach a particular level, it should be reported to the responsible person, and he should act immediately.

In addition, Derby Grey needs to redesign its IT system in such a way so that it can provide the required detail. Since this is continuous monitoring, it may also require revisiting some phases in DMAIC.

6.2.2 DMADV: The application of these methods is aimed at creating a high-quality product, keeping in mind customer requirements at every stage of the product. It is an improvement system which is used to develop *new* processes or products at Six Sigma quality levels. Phases are described in the diagram:



Figure A.18 – DMADV

DMADV is used under the following circumstances:

- A product or process is not in existence.
- Existing process has been optimised using either DMAIC or some other process.
- Projects have strategic importance.
- Multiple processes need to be altered.
- Competitor's performance is changing.
- Customer's behaviour is changing.
- Technology is growing.

6.2.3 Similarities between DMADV and DMAIC

- Both of these six sigma methodologies are based on defects per million opportunities (DPMO).
- Both DMADV and DMAIC use the same kind of six sigma quality management tools.
- Customer's needs are the basic parameter for both six sigma methodologies.

Both DMADV and DMAIC are fundamental six sigma methodologies for improving the quality of product/ process. Broadly, DMAIC deals with improving some of existing processes to make it align with the customer's needs, while DMADV deals with a new design or redesign.



Do You Know?

The steps of both the DMAIC and DMADV methodologies use a variety of common tools.

- To illustrate, Project Charter and Plan, Effort/ Impact Analysis, and Process Mapping are the tools used in the 'Define' process. In addition to this, a Tree Diagram is also used.
- Quality Function Deployment, Measurement Systems Analysis, Check Sheet, and Process Capability are the tools used in the 'Measure' process.
- Histogram, Pareto Diagram, and Run Chart are important tools used in the 'Analyse' process. In addition to this, the Scatter Graph and Statistical Analysis of data are also important tools.

6.2.4 Difference between DMAIC and DMADV

Following table highlights the differences between DMAIC and DMADV.

DMAIC	DMADV
Review the <i>existing processes</i> and fix the problem(s).	Emphasises the design of the product and processes.
More <i>reactive</i> process.	<i>Proactive</i> process.
Increase the <i>capability</i> .	Increase the <i>capacity</i> .
Rupee benefits are <i>quantified</i> rather <i>quickly</i> .	Rupee benefits are more <i>difficult to quantify</i> and tend to be <i>much more long term</i> .
Examples of DMAIC <i>problem-solving</i> methods: <ul style="list-style-type: none"> ▪ Reduce the cycle time to process a patent. ▪ Reduce the number of errors in sales list. ▪ Improve search time for critical information. 	Examples of procedures that the DMADV <i>development method</i> is designed to address: <ul style="list-style-type: none"> ▪ Add a new service. ▪ Create a real-time system. ▪ Create a multiple-source lead tracking system.

6.3 Limitations of Six Sigma

- Six Sigma focuses on quality only.
- Six Sigma does not work well with intangible results.
- Substantial infrastructure investment is required.
- Six Sigma is complicated for some tasks.
- Not all products need to meet Six Sigma standards.
- Six Sigma focuses on a specific type of process only.
- There are a lot of real time barriers that need to be resolved while translating the theoretical concepts into practical applications.

6.4 Lean Six Sigma

Lean Six Sigma is the combination of Lean and Six Sigma which helps to achieve greater results that had not been achieved if Lean or Six Sigma would have been used individually. It increases the speed and effectiveness of any process within any organization. By using lean Six Sigma, organisations will be able to Maximize Profits, Build Better Teams, Minimize Costs, and Satisfy Customers.



Practical Insight

Six Sigma Practices

Wipro is the first Indian company to adopt Six Sigma. Today, Wipro has one of the most mature Six Sigma programs in the industry, ensuring that 91% of the projects are completed on schedule, much above the industry average of 55%.

Six Sigma at Wipro simply means a measure of quality that strives for near perfection. It is an umbrella initiative covering all business units and divisions so that it could transform itself in a world class organization. At Wipro, it means–

- Have products and services meet global benchmarks.
- Ensure robust processes within the organization.
- Consistently meet and exceed customer expectations.
- Make quality a culture within.
- Six Sigma training.

Wipro is using Six Sigma at present on over 500 projects in multiple areas, including project management, market development, and resource utilisation.

(Source- <https://ijrpr.com/uploads/V31SSUE12/IJRPR8975.pdf>)



B. PROCESS INNOVATION

Process Innovation means the implementation of a new or significantly improved production or delivery method (including significant changes in techniques, equipment, and/ or software). Changes, improvements, increase in product or service capability done by addition to a manufacturing or logical system, ceasing to use a process, simple capital replacement or extension, changes resulting purely from changes in factor prices, customization, regular seasonal and other cyclical changes, and trading of new or significantly improved products are not considered innovations.

The process of innovating new solutions could fall into one of these areas:

- **Production:** This is related to processes, equipment, and technology to enhance manufacturing or production processes. This includes computer software.
- **Delivery:** Delivery process innovations involve tools, techniques, and software solutions to help in the supply chain and delivery systems. This includes barcodes, tracking systems, or shipping software.
- **Support Services:** Innovations in processes aren't limited to simply production or delivery but also include areas including purchasing, maintenance, and accounting.



Practical Insight

One of the most widely recognized automobile companies in the world is the American-based multinational manufacturer, Ford Motor Company. Now more than 110 years old, the company was founded by Henry Ford and has succeeded in innovative designs and ideas for more than a century.

One of their most notable innovations came more than 100 years ago with the invention of the world's **first moving assembly line**. The process not only simplified vehicle assembly but also shortened the time necessary to produce a single vehicle from 12.5 hours to 90 minutes. That process innovation, creating an assembly line to speed up production, not only benefited the auto giant but also manufacturers of other consumer goods such as refrigerators and vacuum cleaners. It remains the typical mode of production for businesses today.

(Source- <https://www.cascade.app/studies/ford-strategy-study>)



Concept Insight

BPR & PI

Business Process Re-engineering (BPR) and Process Innovation (PI) are similar concepts that emerged in the early 1990s. BPR focuses on amending existing processes, while PI attempts to implement new processes in an organisation. In many ways, PI is more radical than BPR because it is changing the overall structure of an organisation, whereas BPR is streamlining processes that are already in place.

Bikes are assembled by passing them along a continuous moving band of metal & rubber and adding parts to each one in a prearranged order to arrive at the finished product. This process can be upgraded in terms of efficiency by using automated machines to do some of the repetitive actions. In this manner, the process is being redesigned to include an enhanced automated system to make it more efficient. In other words, Business Process Re-engineering is being used to improve the existing process. But the process itself *could be redesigned from scratch*. For example, the bike could be manufactured by giving all the parts to a team of specialists and asking them to work together to make it. This will mean creating *completely new processes*, which may or may not be more efficient than those of the existing system. But the “process vision” of providing better satisfaction to a team of workers from the production process itself may supersede the efficiency issues. In this example, Process Innovation results in entirely new process to manufacture the bike, even if we haven't defined them – it's up to the workers to decide.



SUMMARY

- ❑ Lean System is an organized method for waste minimization without sacrificing productivity within a manufacturing system. Lean implementation emphasizes the importance of optimizing workflow through strategic operational procedures while minimizing waste and being adaptable.
- ❑ Just in Time - System whose objective is to produce or to procure products or components as they are required by a customer or for use, rather than for stock. just-in-time system Pull system, which responds to demand, in contrast to a push system, in which stocks act as buffers between the different elements of the system such as purchasing, production and sales.

Features of JIT

Material – handling cost are reduced.

Labour idle time gets reduced.

JIT creates urgency for eliminating defects as quickly as possible.

The company can respond to customer demand faster.

Carefully selected suppliers capable of delivering high quality materials in a timely manner directly at the shop – floor, reducing the material receipt time.

Pre- requisites of JIT - Low variety of goods, Vendor reliability, Good communication, Demand stability, TQM, Defect free materials, Preventive maintenance.

Impact of JIT System – Wastes costs like unnecessary levels of obsolete inventory, defective products, rework, etc, overhead costs like material handling, facilities, and quality inspection costs of staff, equipment, fixed assets, facilities, and rent associated with the warehouse etc. get eliminated and When a company achieves a higher level of product quality, along with ability to deliver products on the dates required, customers may be willing to pay a premium .

Backflushing in a JIT System

- a) Backflushing requires no data entry of any kind until a finished product is completed. At that time the total amount finished is entered into the computer system, which multiplies it by all the components listed in the bill of materials for each item produced. This yields a lengthy list of components that should have been used in the production process and which are subtracted from the beginning inventory balance to arrive at the amount of inventory that should now be left on hand.
 - b) Problems with backflushing – Incorrect production reporting, Incorrect scrap reporting, Impossible lot tracing, Inaccurate inventory records.
- ❑ Kaizen Costing –
 - a) Kaizen means continual improvement. The kaizen strategy aims to involve workers from multiple functions and levels in the organization in working together to address a problem or improve a particular process.

- b) Kaizen costing principals - gradual improvements in the existing situation, at an acceptable cost, collective decision making and application of knowledge, no limits to the level of improvements that can be implemented, setting standards and then continually improving these standards to achieve long-term sustainable improvements, focus on eliminating waste, improving systems, and improving productivity, involves all employees and all areas of the business.
- ❑ 5 S's - It explains how a workspace should be organized for efficiency and effectiveness by identifying and storing the items used, maintaining the area and items, and sustaining the new order. 5 S include Sort, Set in Order, Shine, Standardise, Sustain.
 - ❑ Total Productive Maintenance - Total Productive Maintenance (TPM) is a system of maintaining and improving the integrity of production and quality systems. TPM helps in keeping all equipment in top working condition so as to avoid breakdowns and delays in manufacturing processes.
 - a) TPM performance is measured by Overall Equipment Effectiveness (OEE) measure which needs to quantify losses due to equipment failure, set-ups, idle time, stoppages, reduction in speed, reduction in yield, quality defects and rework.
 - b) $\text{Performance} \times \text{Availability} \times \text{Quality} = \text{OEE} \%$
 - ❑ Cellular Manufacturing – In the assembly line multiple cells are used. Each cell comprises of one or more machines which accomplish a certain task. The product moves from one cell to the next, each station completing part of the manufacturing process. U-shaped design is given to these cells because this allows for the supervisor to move less and have the ability to more readily watch over the entire process.
 - a) Goals of cellular manufacturing - move quickly, make wide variety of similar products, very less wastes.
 - b) Advantages – Flexibility in operations, changes easy to make, variety of product scaling, minor changes can be easily and quickly implemented, conducted by logic so reduces flow time, flow distance, floor space, inventory, handling, scheduling transactions, and scrap and rework, production and quality controls facilitated, improves group cohesiveness among employees.
 - c) Limitations – Decrease in production flexibility, difficulty in realignment of cells in case of decrease in demand, changes in flow may be very costly.
 - ❑ Six Sigma - It is quality improvement technique whose objective to eliminate defects in any aspect that affects customer satisfaction. The premise of Six Sigma is that by measuring defects in a process, a company can develop ways to eliminate them and practically achieve “zero defects”. The standard measure of Six Sigma is 34 errors per million.
 - ❑ Process Innovation - Process innovation means the implementation of a new or significantly improved production or delivery method (including significant changes in techniques, equipment and/ or software).



TEST YOUR KNOWLEDGE- MCQS

MCQ 1

5S fits in which stage of the PDCA cycle in the context of the organization striving for continuous improvement?

Options

- a. Plan
- b. Do
- c. Check
- d. Action

Key – b

Reason – Plan and Do are enablers for continual improvement, while Check and Action are results. 5S, being the foundation of TPM (even all the lean practices that eventually led to TQM), acts as the enabler for continual improvement and fits in at the Do stage.

MCQ 2

Which one is not a benefit of Shine?

Options

- a. Less production downtime
- b. Happier employees
- c. Improved quality
- d. Inventory reduction

Key – d

Reason – It is necessary to keep the work area clean and safe. Shining is also an inspection process for the area, i.e., is everything in good condition? This leads to less production time, happier employees by reducing their stress levels, and improved quality. Inventory reduction is not among the benefits of shine.

MCQ 3

Which of the following does Kaizen improvement process not focus on?

Options

- a. 5S
- b. Poka-Yoke
- c. Just-in-time principles
- d. Improvement by innovation

Key – d

Reason – Kaizen is lean thinking and structured around the core premise of continuous improvement rather innovation hence Kaizen focuses on first three options only.

MCQ 4

Which of the following is not a tool used in the 'Define' process in the DMAIC Model of Six Sigma?

Options

- a. Project charter and plan
- b. Check sheet
- c. Effort/ impact analysis
- d. Process mapping

Key – b

Reason – Project charter and plan, Effort/impact analysis, and process mapping are the tools used in the 'Define' process in the DMAIC Model of Six Sigma. In addition to this, tree diagram is also used.

The Check Sheet (Defect Concentration Diagram), is a structured form for collecting and analyzing data. It is one among the 7 Basic Quality Tools. The check sheet is a form used to collect data in real time at the location where the data is generated. The data it captures can be quantitative or qualitative. When the information is quantitative, the check sheet is sometimes called a tally sheet. It is used in the 'Measure' process.

MCQ 5

What will be overall equipment effectiveness, if second is ideal cycle time; planned production time is 7 hour and out of total count of 19,240 units, the good count are 18,848 units.

Options

- a. 97.96%
- b. 76.35%
- c. 74.79%
- d. None of these

Key – c

Reason – Formula for calculating Overall Equipment Effectiveness (OEE) can be either of Availability × Performance × Quality or (Good Count × Ideal Cycle Time) / Planned Production Time

$(18,848 \text{ units} \times 1.0 \text{ seconds}) / (420 \text{ minutes} \times 60 \text{ seconds}) = 0.7479 (74.79\%)$

MCQ 5

Which principle or technique is considered as the base platform for TPM?

Options

- a. Six sigma
- b. 5S
- c. SMED
- d. Kaizen

Key – b

Reason – The traditional approach to TPM was developed in the 1960s and consists of 5S (Sort, Set in Order, Shine, Standardize, and Sustain) as a foundation and eight supporting activities (sometimes referred to as pillars).



TEST YOUR KNOWLEDGE

Just in Time

1. Pearson Metal and Motor Works (PM²W) deals in manufacturing of the copper wired electronic motor, which is specifically designed. PM²W is thinking to shift from traditional system to JIT system as part of process innovation.

CEO among the other top bosses at PM²W are hopeful that implementation of JIT will not only improve value in value chain for end consumer, but also improve overall manufacturing cycle efficiency. JIT pre-implementation team was formed to evaluate the probabilities, which collects following actual and estimated data about process –

Activity Category	Traditional System (Actual)	JIT System (Estimated)
Inspection	40	30
Storage	80	20
Moving	20	10
Processing	60	40

All data in minutes

Further, PM²W decided to practice single piece flow under JIT. PM²W received an order which is due to manufacture and delivered for 10 such motors. Total available production time to produce what customer demands is 480 minutes out of which it normal practice that 30 minutes will be spent in shutdown and cleaning. CEO is also considering JIT purchase apart from JIT production.

Required

- (i) EXPLAIN just in time.
 - (ii) CALCULATE the 'takt time' and INTERPRET the results.
 - (iii) ADVISE whether company should shift to JIT.
2. A manufacturer is considering implementing Just in time inventory system for some of its raw material purchases. As per the current inventory policy, raw materials required for 1 month's production and finished goods equivalent to the level of 1 week's production are kept in stock. This is done to ensure that the company can cater to sudden spurt in consumers' demand. However, the carrying cost of inventory has been increasing recently. Hence, the consideration to move to a more robust just in time purchasing system that can reduce the inventory carrying cost. Details relevant to raw material inventory are given below:
 - The average inventory of raw material held by the company throughout the year is ₹1 crore. Procurement of raw material for the year is ₹12 crore. By moving to just in time procurement system, the company aims at eliminating holding this stock completely in its warehouse. Instead, suppliers of these materials are ready to provide the goods as per its production requirements on an immediate basis. Suppliers will now be responsible for quality check of raw material such that the raw material can be used in the assembly line as soon as it is delivered at the company's factory shop floor.

- Increased quality check service done by the suppliers as well as to compensate them for the risk of holding the inventory to provide just in time service, the company is willing to pay a higher price to procure raw material. Therefore, procurement cost will increase by 30%, total procurement cost will be ₹15.6 crore per year. Consequently, quality check and material handling cost for the company would reduce by ₹1 crore per year. Similarly, insurance cost on raw material inventory of ₹20 lakh per year need not be incurred any longer.
- Raw material is stored in a warehouse that costs the company rent of ₹3 crore per annum. On changing to Just in time procurement, this warehouse space would no longer be required.
- Production is 1,50,000 per year. The company plans to maintain its finished goods inventory equivalent to 1 week's production. Despite this, in order to have a complete cost benefit analysis, the management is also factoring the possibility of production stoppages due to the unavailability of raw material from the suppliers. This could happen due to of delay in delivery or non-conformance of goods to the standard required. Labor works in one 8-hour shift per day and will remain idle if there is no material to work on. Due to the stoppage of production for the above reason, it is possible to have stockout of 3,000 units in a year. Stockout represents a lost sales opportunity due to unavailability of finished goods, the customer walks away without purchasing any product from the company. Therefore, in order to reduce this opportunity cost and to make up for the lost production hours, labor can work overtime that would cost the company ₹10 lakh per annum. This is the maximum capacity in terms of hours that the labor can work. With this overtime, stockout can reduce to 2,000 units.
- Currently, the sale price of product is ₹5,000 per unit, variable production cost is ₹2,000 per unit while variable selling, general and administration (SG&A) cost is ₹750 per unit. Raw material procurement cost is currently ₹800 per unit, that will increase by 30% to ₹1,040 per unit under Just in time inventory system.
- On an average, the long-term return on investment for the company is 15% per annum.

Required

- (i) CALCULATE the benefit or loss if the company decides to move from the current system to Just in Time procurement system.
- (ii) RECOMMEND factors that the management needs to consider before implementing the just in time procurement system.

Total Productive Maintenance (TPM)

3. Pacific Coast Company Ltd. manufactures spare parts. It works in two shifts of 9 hours for 6 days in a week. Lunch break is 30 mins and other miscellaneous breaks add up to 15 minutes. The following details are collected for the last 4 weeks by the TPM team for one of their important equipment

Hours for Planned Preventive Maintenance = 15 minutes per shift

For Breakdown Maintenance = 6 hours total

Set up Changes = 14 hours total
 Power Failure = 4 hours total
 Standard Cycle Time per piece = 3 minutes
 No of Parts Produced per shift = 140
 Parts Accepted per shift = 131

Required

CALCULATE 'OEE'.

4. GVK Pharmaceuticals Ltd. is producing medication products (pills, balms etc.) and can be called high volume based production environment. There are several different automated production machines located in the plant, through which production of medicines is accomplished and fulfilled the demands. Plant operates in double shift a day each consisting of 8 hours with 25 minutes' lunch break and tea break of 10 minutes. Following data pertains to automated machine 'X-78'.

X-78

19 April 2023, Wednesday

Breakdown, repair and start up time (unplanned)	90 minutes
Standard cycle time	2.5 minutes <i>per tablet</i>
Quality loss due to scrap, rework, and rejection	40 tablets
Total quantity produced	280 tablets

Required

CALCULATE 'OEE'.

5. Hindustan Ltd. supplies the following information relating to a vital equipment used in its production activity for April 2023:

Total time worked during the month	210 hrs.
Total production during the month	2,800 units
No. of units accepted out of total production	2,520 units
Standard time for actual production of the month	180 hrs.
Time lost during the month	28 hrs.

Required

- (i) STATE an appropriate approach to measure the total productive maintenance performance of an equipment.
- (ii) Quantify the total productive maintenance performance of the above-mentioned equipment by using the approach stated in (i) above.
- (iii) COMMENT on the effectiveness of maintenance of the equipment.



ANSWERS/ SOLUTIONS

1. (i) **Just-in-time (JIT)** is a collection of ideas that streamline a company's production process activities to such an extent that wastage of all kind viz., of time, material and labour systematically driven out of the process with single piece flow after considering takt time.

In JIT, production facility is required to be integrated with vendor system for signal (Kanban) based automatic supply which depends upon demand based consumption. Under JIT system of inventory storage cost is at lowest level due to direct issue of material to production department as and when required and resultantly less/no material lying over in store or production floor.

Prerequisite of JIT system is integration with vendor, if vendor is not integrated properly or less reliable, then situation of stock out can arise and which can result into loss of contribution.

Multitasking by employee is another key feature of JIT, group of employees should be made based upon product instead based upon function. Hence, functional allocations of cost become less appropriate.

Overall, JIT enhance the quality into the product by eliminating the waste and continuous improvement of productivity.

- (ii) **Takt Time** is the maximum available time to meet the demands of the customer; this will help to decide the speed of/ at manufacturing facility.

Takt time is the average time between the start of production of one unit and the start of production of the next unit, when these production starts are set to match the rate of customer demand.

$$\text{Takt Time} = \frac{\text{Available Production Time}}{\text{Total Quantity Required}}$$

Here, Available Production Time is 'total available time for production' – 'planned downtime i.e., spent in shutdown and cleaning' i.e., 450 minutes = 480 minutes – 30 minutes.

Total Quantity Required is 10 units.

$$\text{Takt Time} = \frac{450 \text{ minutes}}{10 \text{ units}} = 45 \text{ Minutes}$$

Note - Heijunka can be applied in order to reduce variation between 'Takt times' over the production.

Interpretation

Customer's demand is 10 units, to calculate the takt time, divide the available production time (in minutes) by the total quantity required. The takt time would be 45 minutes. This means that process must be set up to produce one unit for every 45 minutes throughout the time available. As order volume increases or decreases, takt time may be adjusted so that production and demand are synchronized.

(iii) Advise on Shifting to JIT

To evaluate how much of the old cycle time was spent in inventory, we need to know how organizations assess the efficiency of their **manufacturing processes**. One commonly used measure is process cycle efficiency and to calculate the same every process is breakdown into combination of activities such as value added activities, non-value added activities and non-value added activities but strategic activities. In order to generate highest value to customer, only *value added activities* are included in process. But those non-value added activities, which are strategic in nature, also need to be part of process. Therefore, it may be possible that entire process is not efficient.

To measure efficiency of process, managers keep track of the relation between 'times taken by value added activities' in comparison 'total cycle time'. Such relation/ratio is processing cycle efficiency.

$$\text{Process Cycle Efficiency} = \frac{\text{Value Added Time}}{\text{Cycle Time}}$$

Processing time is considered as value added time; whereas time spend on inspection, storage and moving is non-value added time and included in cycle time. The higher the percentage, less the time (and costs) needs to be spent on non- value added activities such as moving and storing etc.

Computation of Processing Cycle Efficiency

Sr. No.	Activity Category	Traditional System (Actual)	JIT System (Estimated)
A.	Inspection	40	30
B.	Storage	80	20
C.	Moving	20	10
D.	Processing	60	40
E.	Value Added Time	60	40
F.	Cycle Time ... (A)+(B)+(C)+(D)	200	100
	Process Cycle Efficiency ... (E)/ (F)×100	30%	40%

Of the 200 minutes required for manufacturing cycle under PM²W's traditional system, only 60 minutes were spent on actual processing. The other 140 minutes were spent on non- value added activities, such as inspection, storage, and moving. The process cycle efficiency formula shows that processing time equalled to 30% of total cycle time. The cycle time is reduced substantially in the JIT system from 200 minutes to 100 minutes. In addition to this, the amount of time that used up in inventory i.e., non-value-added activities is also reduced. Therefore, process cycle efficiency has been increased from 30% to 40%. This significant improvement in efficiency over the previous system comes from the implementation of JIT system. Therefore, it is advantageous to shift to JIT system.

2. (i) Implementing Just in time procurement system will benefit the company as explained below:

Particulars	Current Purchasing Policy (₹)	JIT Procurement System (₹)
Raw material procurement cost per year	12,00,00,000	15,60,00,000
Quality check and material handling cost (<i>No longer required in JIT</i>)	1,00,00,000	---
Insurance Cost on raw material inventory (<i>No longer required in JIT</i>)	20,00,000	---
Warehouse rental for storing raw material (<i>No longer required in JIT</i>)	3,00,00,000	---
Overtime Charges under JIT to reduce Stockouts (note1)	---	10,00,000
Stockout Cost (note 2)	---	40,20,000
Total Relevant Cost	16,20,00,000	16,10,20,000

Therefore, moving to just in time procurement system results in savings of ₹9,80,000 per year for the company. **If reinvested**, long-term return on investment for the company at 15% would yield a return of ₹1,47,000 per year.

In addition, by switching over to JIT system, the company will also save working capital requirement of ₹1 crore on account of average inventory of raw material held at present. The company can earn a further 15% on this amount i.e. ₹15,00,000 per year.

Therefore, total benefit for the company would be ₹26,27,000 per year.

Note 1: Should overtime cost be incurred to reduce Stockouts?

Contribution per unit = Sale price - Variable production cost - Variable selling, distribution cost per unit; Variable production cost under the just in time system = ₹2,000 + ₹(1,040-800) = ₹2,240 per unit; Contribution per unit = ₹5,000 - ₹2,240 = ₹2,760 per unit = ₹2,010 per unit.

Overtime cost can reduce stockouts from 3,000 units to 2,000 units, that is customers' demand of 1,000 units more can be met.

Contribution earned from selling these 1,000 units = 1,000 × ₹2,010 per unit = ₹20,10,000.

Therefore, the contribution earned of ₹20,10,000 is more than the related overtime cost of ₹10,00,000. Therefore, it is profitable to incur the overtime cost.

Note 2: Stockout Costs

Out of the total shortfall of 3,000 units, by spending on overtime 1,000 units of demand can be met. Therefore, actual stockout units is only 2,000 units. As explained above, contribution per unit is ₹2,010 per unit. Therefore, stockout cost = 2,000 units × ₹2,010 per unit = ₹40,20,000.

- (ii) The company plans to eliminate its raw material inventory altogether. Raw material will be delivered as per the production schedule directly at the factory shop floor, from whence production will begin. The management should therefore carefully consider the following points:
- The entire production process has to be detailed and integrated sequentially. This is essential to know because it should be known in advance when in the sub-assembly process is each raw material is required and in what quantity.
 - Since production is dependent on delivery and quality of raw material, heavy reliance is being placed on suppliers. They should be able to guarantee timely delivery of raw material of the appropriate quality. The company is paying a premium of 30% of the original cost, that is ₹240 per unit (₹1,040 - ₹800 per unit) in order to ensure the same. Each unit gives a contribution of ₹ 2,010 per unit, which is 40.2% of the sale price per unit. Lost sales opportunities due to unavailability of raw material or non-conformance of the material can result in substantial losses to the company. While a portion of this has been factored while doing the cost benefit analysis of implementing Just-in-time systems, it needs careful consideration and monitoring even after implementation. Therefore, to hedge its loss, the management and suppliers should agree on penalties or costs the supplier should incur should there be any delay or non-conformance in quality of materials beyond certain thresholds.
 - Accurate prediction of sales trends is important to determine the production schedule and finished goods planning.
 - Continuous monitoring of the system even after implementation is essential to ensure smooth operations. Management commitment and leadership support are essential for its successful implementation and working.

3. Calculation of Shifts

Days per week	...(A)	6
Shifts per week	...(B)	2
Total Working Shifts per week	...(C = A × B)	12
Total Weeks	...(D)	4
Total Shifts	...(E = C × D)	48

Calculation of Un-Planned Downtime

Breakdown Maintenance (in mins)	360
Set up Changes (in mins)	840
Power Failure (in mins)	240
Total	...(A) 1,440
Loss of Minutes per shift	...(A/ 48) 30

Calculation of Planned Production Time

	Mins.
Total time (9 hrs. × 60 mins.)	540
Less: Planned downtime	
Lunch break	30
Miscellaneous breaks	15
Preventive maintenance	15
Planned Production Time	480

$$\text{Availability Ratio} = \left\{ \frac{480 \text{ mins.} - 30 \text{ mins.}}{480 \text{ mins.}} \right\} \times 100$$

$$= 93.75 \%$$

$$\text{Actual Production} = 140 \text{ units per shift}$$

$$\text{Standard time} = 3 \text{ minutes}$$

$$\text{Standard Time Required} = 140 \text{ units} \times 3 \text{ minutes}$$

$$= 420 \text{ minutes}$$

$$\text{Actual Time Taken} = 480 \text{ mins.} - 30 \text{ mins.}$$

$$= 450 \text{ minutes}$$

$$\text{Performance Ratio} = \left\{ \frac{420 \text{ mins.}}{450 \text{ mins.}} \right\} \times 100$$

$$= 93.33\%$$

$$\text{Quality Ratio} = \left\{ \frac{131 \text{ parts}}{140 \text{ parts}} \right\} \times 100$$

$$= 93.57\%$$

$$\text{Thus, OEE} = 0.9375 \times 0.9333 \times 0.9357 = 81.87\%$$

4. Calculation of Planned Production Time

	Mins.
Total time	480
Less: Planned downtime	
tea break	10
lunch break	25
Planned Production Time	445

$$\text{Availability Ratio} = \left\{ \frac{445 \text{ mins.} - 45 \text{ mins.}}{445 \text{ mins.}} \right\} \times 100$$

$$= 89.89 \%$$

$$\text{Actual Production} = 140 \text{ tablets per shift}$$

$$\text{Standard time} = 2.5 \text{ minutes}$$

$$\text{Standard Time Required} = 140 \text{ units} \times 2.5 \text{ minutes}$$

$$= 350 \text{ minutes}$$

$$\text{Actual Time Taken} = 445 \text{ mins.} - 45 \text{ mins.}$$

$$= 400 \text{ minutes}$$

$$\text{Performance Ratio} = \left\{ \frac{350 \text{ mins.}}{400 \text{ mins.}} \right\} \times 100$$

$$= 87.50\%$$

$$\text{Quality Ratio} = \left\{ \frac{140 \text{ tab.} - 20 \text{ tab.}}{140 \text{ tab.}} \right\} \times 100$$

$$= 85.71\%$$

$$\text{Thus, OEE} = 0.8989 \times 0.8750 \times 0.8571$$

$$= 67.41\%$$

5. (i) The most important approach to the measurement of TPM performance is known as Overall Equipment Effectiveness (OEE) measure. The calculation of OEE measure requires the identification of “six big losses”.

- Equipment Failure/ Breakdown
- Set-up/ Adjustments
- Idling and Minor Stoppages
- Reduced Speed
- Reduced Yield and
- Quality Defects and Rework

The first two losses refer to time losses and are used to calculate the availability of equipment. The third and fourth losses are speed losses that determine performance efficiency of equipment. The last two losses are regarded as quality losses.

$$\text{Performance} \times \text{Availability} \times \text{Quality} = \text{OEE} \%$$

OEE may be applied to any individual assets or to a process. It is unlikely that any manufacturing process can run at 100% OEE.

$$\begin{aligned} \text{(ii) Availability Ratio per shift} &= \left\{ \frac{210 \text{ hrs.}}{210 \text{ hrs.} + 28 \text{ hrs.}} \right\} \times 100 \\ &= 88.24 \% \\ \text{Performance Ratio} &= \left\{ \frac{180 \text{ hrs.}}{210 \text{ hrs.}} \right\} \times 100 \\ &= 85.71\% \\ \text{Quality Ratio} &= \left\{ \frac{2,520 \text{ units}}{2,800 \text{ units}} \right\} \times 100 \\ &= 90.00\% \\ \text{Thus, OEE} &= 0.8824 \times 0.8571 \times 0.90 \\ &= 68.06\% \end{aligned}$$



This question has been solved by considering “**Time Available equals to Total Time Worked plus Time Lost**”.

(iii) Comment

World Class OEE is 85% or greater, Hindustan Ltd.’s OEE is somewhere around 68%. It just means that company got some opportunities for improvement. Hindustan Ltd. may improve OEE by collecting information related to all downtime and losses on equipment, analyzing such information through graphs and charts, making improvement decisions thereon like autonomous maintenance, preventive maintenance, reduction in set up time etc. and implementing the same.
